New Scientist

WEEKLY 8 February 2025

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HOW DEEPSEEK CHANGES THE FUTURE OF AI

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Instant Expert

Incredible cosmology

Powerful telescopes and computers are rapidly advancing what we know about the universe. From the nature of dark matter and dark energy to the origins of the cosmos itself, scientists are tackling big questions that challenge our understanding of reality. Join six world-leading experts as they delve into the latest research on 15 March at London's Congress Centre.

newscientist.com/events

Tour

The science of whisky cruise: Scotland

Explore how whisky is made on this tour of renowned distilleries, sailing from Inverness to Islay. Understand whisky's complexity and variety through a programme of sensory experiences delivered by Barry C. Smith, a founding director of the University of London's Centre for the Study of the Senses. This eight-day trip starts on 1 September and costs £5249.

newscientist.com/tours

Podcast

Weekly

The team speak to climate scientists to learn whether there are signs that global heating is accelerating. They also find out about Chinese AI company DeepSeek, which recently wiped $600 billion off the market value of chip company Nvidia. Plus, hear the first ever recording of a new form of dolphin behaviour: aerial urination.

newscientist.com/nspod

JOHANN SCHUMACHER/ALAMY

Symmetrical nature The universe has a penchant for symmetry

SIMON GROSSET/ALAMY

Whisky galore Discover the science at work in famous distilleries

Video

A helping hand

A robotic hand exoskeleton is able to assist expert pianists when they hit a plateau in their abilities by helping them play faster. Robotic exoskeletons have long been used to rehabilitate people who can no longer use their hands due to injury or ill health. Now, Sony Computer Science Laboratories in Tokyo is using them to improve the skills of people without these conditions.

youtube.com/newscientist

Newsletter

Lost in Space-Time

Mathematician Emmy Noether is often overlooked in the history of science, but she was described as a creative genius by Albert Einstein. In this issue, John and Mary Gribbin consider how Noether's theorem about symmetry enabled the modern studies of particle physics and quantum theory.

newscientist.com/lost-in-space-time

Podcast

"The carbon footprint of artificial intelligence services is under-appreciated"

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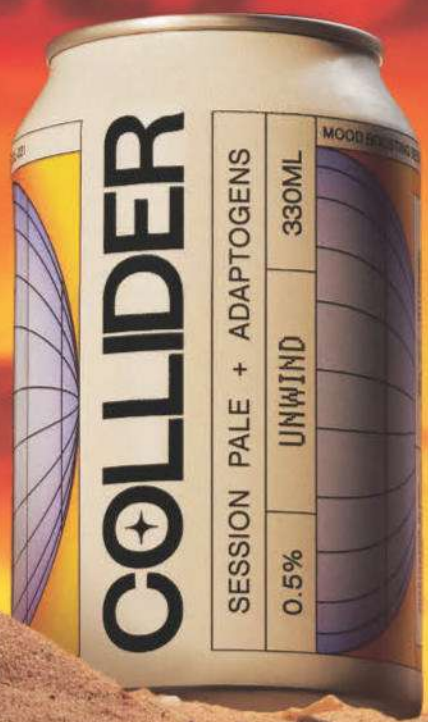

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All to play for

China has entered the generative AI game, with gains to be had for many

IN POKER, the value of the cards in your hand is often less important than what your competitors think you might hold. You don't need a royal flush as long as you can convince others you have one.

Sam Altman, CEO of OpenAI, knows this well, having played poker extensively during his student days. Following the astronomical success of its generative artificial intelligence tool ChatGPT, the company has convinced many backers that it holds all the aces, telling the world that scale is the key to progress and that betting on this will reap big rewards.

On 21 January, Altman announced Stargate, a $500-billion plan to build vast data centres for future AI models. As he said in an interview in 2023: "It's totally hopeless to compete with us."

But Chinese AI company DeepSeek now looks to have called his bluff. It sent shock waves through Silicon Valley over the past two weeks with the release of AI models that are apparently as capable as OpenAI's best, but at a fraction of the cost and computational power

"DeepSeek has punctured the idea that US companies hold a secret recipe for building AI"

(see page 8). This young upstart, with less than a tenth as many employees as OpenAI, has punctured the idea that US companies hold some secret recipe for building AI or that they need such enormous resources to do so.

For those concerned about the accumulation of power in Silicon Valley, the arrival of competition is welcome, but DeepSeek's model brings concerns of its own. For one thing, its answers stick closely to the Chinese government's party line, and it even censors itself in real time. Security researchers have also warned that it lacks robust guardrails against inappropriate use.

Nevertheless, its arrival on the scene suggests there are huge innovations in generative AI yet to come. Plus, cheaper models that require less computational power should open the door to entirely new applications for the technology, which may also make it affordable to more people and less damaging to the planet. With more players around the table, the stakes couldn't be higher. ▮

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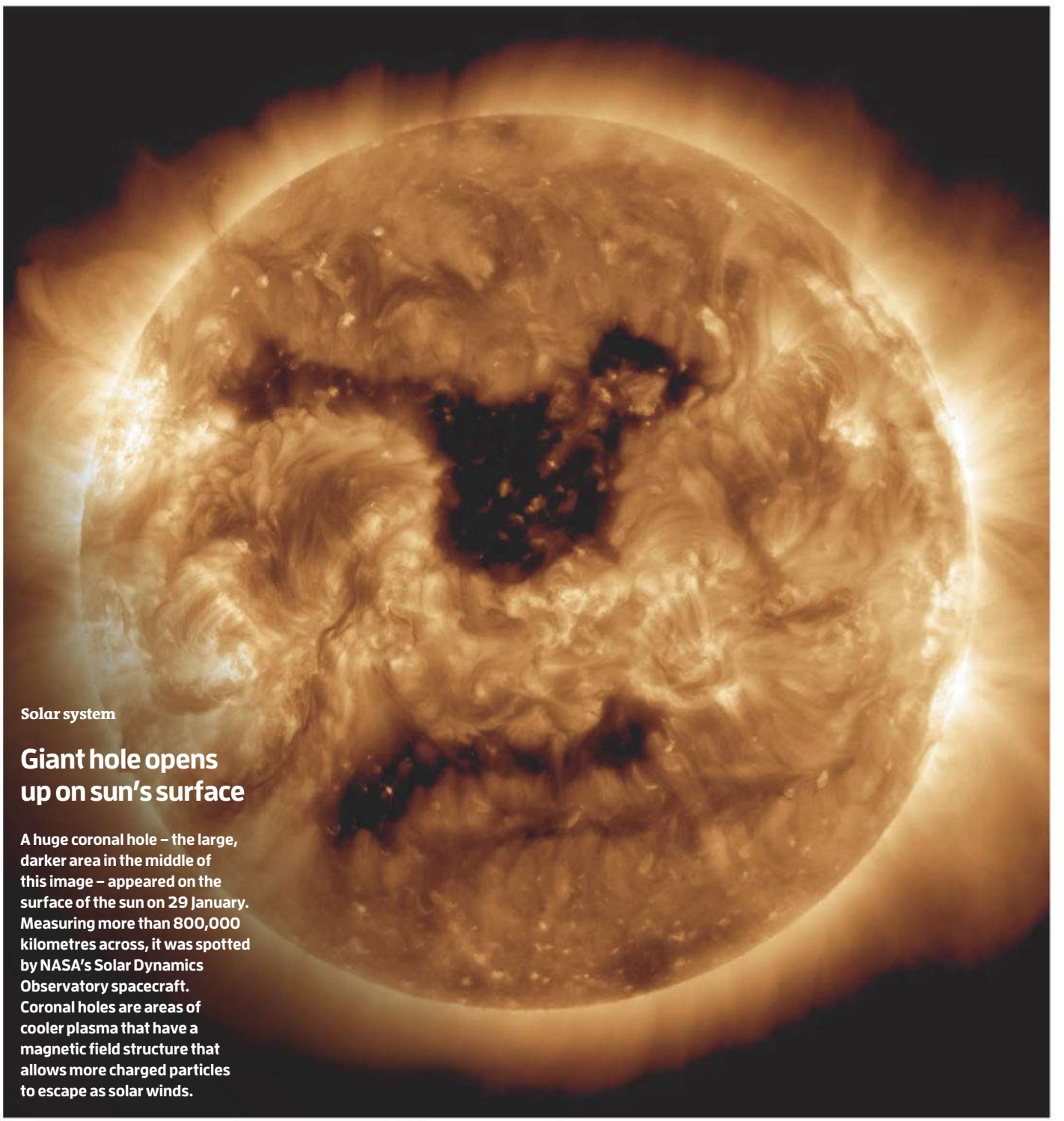


Solar system

Giant hole opens up on sun's surface

A huge coronal hole – the large, darker area in the middle of this image – appeared on the surface of the sun on 29 January. Measuring more than 800,000 kilometres across, it was spotted by NASA's Solar Dynamics Observatory spacecraft. Coronal holes are areas of cooler plasma that have a magnetic field structure that allows more charged particles to escape as solar winds.

SDO/NASA/SWNS

Analysis Artificial intelligence

Does DeepSeek herald AI's future?

The success of Chinese firm DeepSeek suggests tech companies can train and run powerful AIs without consuming vast amounts of power, finds **Alex Wilkins**

SINCE the boom in artificial intelligence got under way, US tech bosses have demanded a vast expansion of data centres and energy infrastructure to support further progress and uptake of the technology. Now, the shock wave triggered by Chinese company DeepSeek is challenging that view. While there are serious safety and censorship concerns with the company's AI model, many in the industry think DeepSeek's advances could lead to sweeping changes in the way such models are developed and used, as well as significant energy savings and a lower climate burden. Are they right?

DeepSeek's R1 model was a shock to US AI companies, and a mystery. How did a team of a few hundred researchers and a reported budget of several million dollars produce a model as capable as OpenAI and Google's best, with their several thousand-strong teams and billion-dollar budgets? The secret wasn't down to a single magic ingredient, says Artur Garcez at City St George's, University of London, but a combination of clever engineering tricks that were individually already known about.

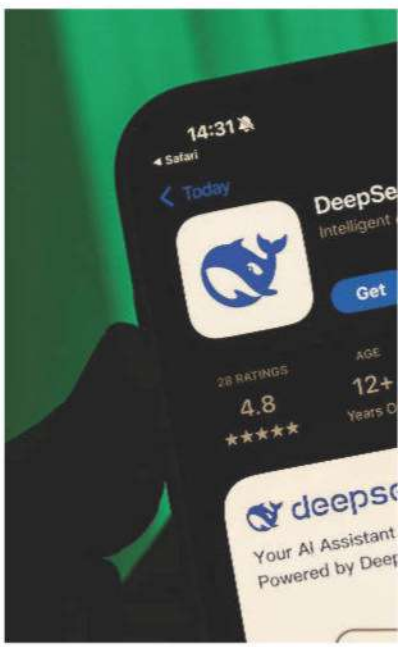
One of the most successful methods in AI training is what's called reinforcement learning, where researchers show an AI what success looks like and leave it to figure out the rules using a form of trial and error. This was key to Google DeepMind's achievements with its chess and protein-folding AI systems, as success in a chess game or predicting a protein's shape can be easily defined. However, researchers found it more difficult to translate this method to large language models, where success is less concrete.

"DeepSeek's secret wasn't down to a single magic ingredient but a combination of tricks"

While OpenAI's GPT models use a form of reinforcement learning, where they are given feedback about which answers people prefer, this isn't really reinforcement learning in the way that people have traditionally used it. Like the GPT models, DeepSeek's R1 was first trained on vast amounts of text from the internet, but it was then left to work out how to reason by itself using actual reinforcement learning, without needing human feedback, says Garcez.

To do this, engineers at DeepSeek focused on applying reinforcement learning to problems where they could define clear answers, such as in maths and coding, and also had the model produce many answers at once that it could compare side by side. Only then was the model shown human-labelled examples to fine-tune its capabilities in other domains.

After the model had been trained in this way, DeepSeek researchers found a way to transplant its reasoning capabilities into smaller, open-source models that had already been trained, in a step they call distillation. This stage of the process is a large reason why so many people are starting to doubt that US tech companies need as much computing power as they say they do, says Garcez.



IFEEL STOCK/ALAMY

"OpenAI and some of its competitors were going a bit crazy on scale. There was this mantra – scale is all you need – and they were scaling up every year," says Garcez. "What we see with the distillation and the gains that they're showing is that you don't really have as much of a reason for scaling up."

If tech companies need less computing power to train models, this might mean AI doesn't have to be as damaging to the climate as it currently is, and that plans like a $500 billion AI infrastructure project in the US might not need to go ahead.

But US tech companies have been quick to push back against this. Satya Nadella, the CEO of Microsoft, which owns a large stake in OpenAI, posted on X that "as AI

Are US export controls affecting China's AI industry?

In 2022, the US government began implementing export controls that seek to limit China's access to US chips developed for use with artificial intelligence. This doesn't seem to have affected DeepSeek's development – yet.

While DeepSeek trained its R1 model efficiently (see main story), "efficiency gains likely came from having substantial compute access", says Lennart Heim at the RAND Corporation, a think tank based in California.

DeepSeek operates one of Asia's largest clusters of AI chips and has unfettered access to computing resources stored in the cloud, Heim and Sihao Huang at the University of Oxford wrote in a blog post. Such resources potentially helped DeepSeek generate synthetic training data and then discover more efficient techniques through trial-and-error experimentation.

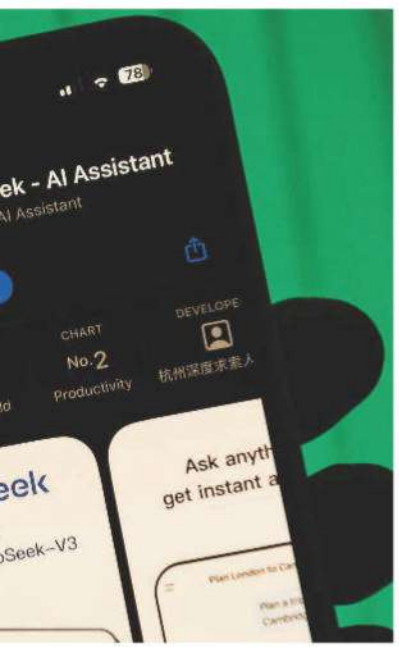
The firm also trained its AI model on NVIDIA H800 chips that were designed to circumvent the initial US export controls. More restrictive export limitations that were implemented in October 2023 haven't yet made their full impact felt, wrote Heim and Huang.

"China is still running pre-restriction data centres with tens of thousands of chips, while US companies are constructing data centres with hundreds of thousands," the pair wrote. "The real test comes when these data centers need upgrading or expansion."

But others see export controls as having mixed results and even spurring Chinese tech companies to develop efficient workarounds.

"US export controls had a huge impact on DeepSeek's innovation, there is no question about that," says Paul Triolo at DGA Group, a global advisory firm in Washington DC. "This highlights the limitations of the export controls."

Jeremy Hsu



DeepSeek's AI model was a shock to researchers when it was released

gets more efficient and accessible, we will see its use skyrocket, turning it into a commodity we just can't get enough of".

"The CEOs, if you speak to them, of course they have to do the hard sell, and they have to predict that AI will need these data centres," says Mirella Lapata at the University of Edinburgh, UK. "But if I can run this stuff

"If tech companies need less computing power to train AI, this may mean it isn't as damaging to the climate"

on my computer, on one [graphics processing unit], why would I actually pay OpenAI to do anything?"

However, another aspect of DeepSeek's R1 model might actually increase the energy demands of AI. Like OpenAI's o1 reasoning models, it uses a method called chain of thought, in which the AI "thinks out loud" and shows its working when asked to respond to a prompt, which researchers have found can improve its performance on some mathematics and coding tasks. If many more people start using AI tools that need to think in this way, it could lead to a greater computational need and cost, as Nadella predicts.

But DeepSeek's thinking time is divided up between several subsystems that are expert in different fields, such as mathematics or coding, in what is known as a mixture of experts model. This will lead to less computational power being needed than using the entire model, says Nikos Aletras at the University of Sheffield, UK. Also, the vast majority of requests might not need the most computationally intensive "thinking" models, says Aletras, leading to lower overall energy costs.

"If I had to explain every single response to you, we would never finish this meeting," says Aletras. "Sometimes [chain of thought] is useful... but if I ask a question that's very straightforward, then I don't need it there."

Ultimately, how much of an effect DeepSeek's innovations will have on the AI industry and its energy consumption will depend on whether US tech companies can show that their approach delivers superior results. But with customers able to use DeepSeek's R1 for less than one-twentieth of the cost of models like OpenAI's o1, the difference in quality would have to be substantial. "If we don't have to pay, why would we? And that means that the energy consumption would be effectively lower," says Lapata. ▮

Space

Asteroid has low chance of hitting Earth in 2032

James Dinneen

AN ASTEROID up to 100 metres wide has a 1-in-83 chance of impacting Earth on 22 December 2032. That risk is enough to have triggered global planetary defence response procedures for the first time.

"This is a historic moment," says Richard Moissl at the European Space Agency (ESA).

The asteroid, dubbed 2024 YR4, was first detected on 27 December 2024 by an automated telescope in Chile that scans for asteroids. It is now at the top of ESA and NASA's impact risk list, with a 1.3 per cent chance of colliding with Earth in about seven years.

That risk of collision combined with the asteroid's size gives it a rating of 3 out of 10 on the Torino scale, a tool used to categorise the potential damage from the impact of comets and asteroids. That means it qualifies as a "close encounter" that could cause "localized destruction". The kinetic energy released on impact could be equivalent to nearly 8 million tonnes of dynamite, according to NASA figures – enough to destroy a city.

"This particular score has never been assigned to any asteroid," says Moissl. "Torino scale 3 gives us a mandate to do things we don't normally do," he says, such as ramping up close monitoring.

Collecting measurements of the asteroid from more powerful telescopes could give a more accurate idea of its collision risk with Earth. This may shift the risk to zero, says Moissl.

1.3%
Chance that the asteroid will collide with Earth in seven years

The asteroid Apophis, which will pass near Earth in 2029, was initially assigned a 4 on the Torino scale when it was first detected in 2004. After more measurements, the risk was downgraded to zero. That detection occurred before globally coordinated planetary defence procedures, as well as automated asteroid detection systems, were in place.

But 2024 YR4 is being treated differently. Moissl says a UN-affiliated group called the International Asteroid Warning Network is working to study the asteroid's trajectory. Another international consortium called the Space Mission Planning Advisory Group has been alerted to the asteroid and could begin planning a proposal on how to defend against a collision, such as deflecting the asteroid with a spacecraft, should that ever become necessary.

Currently, the asteroid "is not cause for concern", says Moissl. "But because it is so unusual, it is something to keep a close eye on." ▮

An illustration of an asteroid passing close to Earth

SHUTTERSTOCK/MIKAEL DAMKIER

Climate change

Antarctic ice sheet may not be as vulnerable as we thought

James Dinneen

A MAJOR ice shelf in Antarctica appears to have survived a period of hot temperatures more than 120,000 years ago, indicating that the West Antarctic ice sheet may not be as vulnerable to complete collapse caused by climate change as we thought – a worst-case scenario that could raise sea levels by metres. But large uncertainties remain.

"It's good news and it's bad news," says Eric Wolff at the University of Cambridge, UK. "We didn't get the worst-case scenario. But I can't put my hand on my heart and say this wouldn't happen in the next century or two."

Human-caused climate change has made the future of the West Antarctic ice sheet uncertain. If we continue to emit high levels of greenhouse gases, some models project the ice sheet will disappear over the next few centuries. In the most extreme scenario projected by the Intergovernmental Panel on Climate Change in 2023, this could raise sea levels by as much as 2 metres by 2100.

Wolff and his colleagues looked at the Ronne ice shelf, a large section of the ice sheet that extends into the ocean, to see how it behaved between 117,000 and 126,000 years ago. During that time, which was part of the last interglacial period, changes in Earth's orbit raised Antarctic temperatures even higher than they are today.

To determine the extent of the Ronne ice shelf during that warm period, the researchers measured concentrations of sea salt in an ice core drilled about 650 kilometres away from the shelf's edge. If the ice shelf had melted during the last interglacial, its edge would have drawn closer to the core's location. As a result, the researchers expected salt concentrations in the core would rise eightfold during those years, because the core's location would have been much closer to the open ocean. "It would have been a seaside resort," says Wolff.

"The ice's stability in the last interglacial suggests a lower chance of collapse as Earth warms"

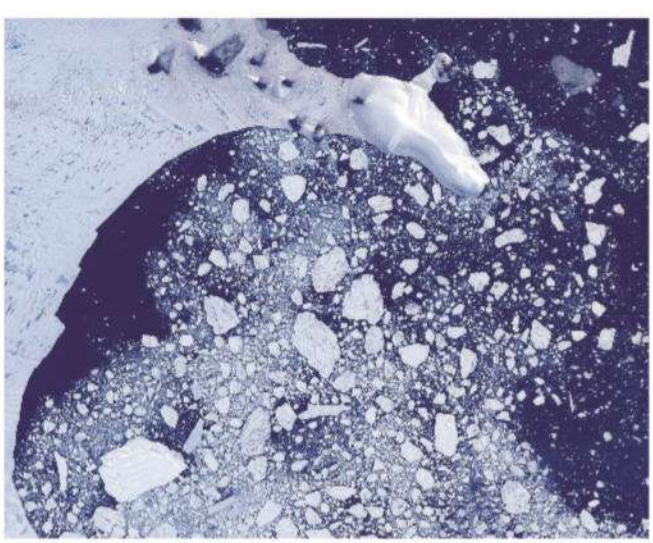
Instead, they found salt concentrations were similar or even lower than those of today, indicating that the edge of the ice sheet remained far away. Measurements of water isotopes in the core, which preserve evidence of weather patterns influenced by changing ice sheets, also indicate the Ronne ice shelf persisted (*Nature*, doi.org/n43g).

The ice's stability at that time suggests a lower likelihood that the West Antarctic ice sheet will collapse as climate change drives up global temperatures, says Wolff. However, he and other researchers say sea level rise due to melting ice still poses a major risk.

"It implies there was not a complete deglaciation of western Antarctica, but it doesn't give us enough information to relax," says Timothy Naish at Victoria University of Wellington in New Zealand.

For one, the survival of the Ronne ice shelf doesn't mean that other areas of ice, like the Thwaites or Pine Island glaciers, didn't melt. In fact, the water isotope record in the core suggests they did, says Wolff.

The dynamics of warming in the last interglacial, which varied by region, are also different from global warming today, when temperatures are rising across the whole planet. For example, warmer ocean waters reaching Antarctica could accelerate melt by intruding under the ice, says Wolff. ▮



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Will the Ronne ice shelf melt due to climate change?

Zoology

Salamanders fill their toes with blood before each step

Sofia Quaglia

HOW salamanders manage to move around on uneven, vertical tree surfaces with such dexterity has long baffled scientists. A new discovery suggests they use a trick out of a horror movie: filling their toes with pools of blood.

While Christian Brown at Washington State University was observing wandering salamanders (*Aneides vagrans*) through a close-up camera in 2021 in a coastal redwood forest, he noticed blood moving in a rhythmic pattern under their translucent skin. Before lifting their foot to take a step, blood inundated the tips of the salamanders' 18 toes. Once they placed their foot, the blood dissipated, and they kept their toes drained while clinging to the surface.

In the lab, Brown's team filmed three tip-toeing salamanders on a clear platform and examined their internal structures. They found that the salamanders could control the flow of blood to each toe via two blood pathways called sinuses. Blood is always flowing throughout the animal's feet, but when the salamander extends its toe tip, it allows more blood to rush in (*Journal of Morphology*, doi.org/g83jj9).

The inflation-then-deflation move changes the toe's stiffness, which probably "has huge implications" for its grip, says Brown. Like an inflated basketball bouncing off the floor versus a flat one sticking, the blood-filled toes appear to help release the animal from a surface.

The move makes sense, especially when you are covered in sticky mucus, says Michael Granatosky at the New York Institute of Technology. It probably takes wandering salamanders less energy to inflate off a surface than to unstick themselves using muscular force. ▮

Solar system

Vast moon ravines carved in minutes

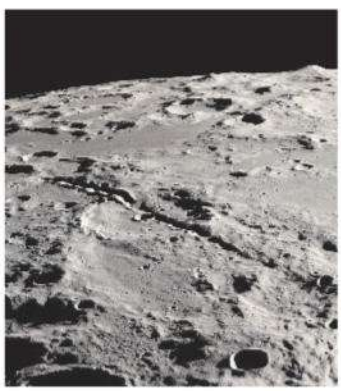
An asteroid strike rapidly formed two valleys that are on the same scale as the Grand Canyon

Matthew Sparkes

A HUGE impact crater near the moon's south pole was formed by an asteroid moving at more than a kilometre a second, releasing energy when it struck equivalent to 130 times that of all the nuclear weapons in existence. Now, researchers say two unusually narrow and straight canyons that splay out from its centre were formed in less than 10 minutes by a chain of debris impacts.

David Kring at the Lunar and Planetary Institute in Houston, Texas, has been researching the 312-kilometre-wide Schrödinger crater for 15 years. The canyons radiating from it have long fascinated him. "They're basically hidden, in some sense mysterious, because they're on the far side [of the moon]," says Kring. "And so they're commonly overlooked."

To learn more, Kring and his colleagues used computer models to investigate the origin of two canyons that extend from the crater. One is Vallis Schrödinger,



NASA/SVS/ERNIE T. WRIGHT

Deep grooves radiate out from Schrödinger crater on the lunar surface

which is 270 kilometres long and 2.7 km deep, while the second, Vallis Planck, is 280 km long and 3.5 km deep. For comparison, the Grand Canyon in Arizona is 446 km long and up to 1.9 km deep.

But while the Grand Canyon was carved by water over millions of years, the lunar canyons are clear, straight grooves formed by vast impact forces in less than 10 minutes, says Kring. The asteroid strike responsible would have spread dust and rubble over the whole moon.

The researchers suggest that it would have driven debris across the lunar surface fast enough to cause craters outside the main one, and these could have been focused into narrow regions by irregularities in the regolith, the loose material that coats the moon.

The researchers calculated that an asteroid impact an estimated 3.81 billion years ago would have been capable of creating the required speed and direction of debris to create the canyons (*Nature Communications*, DOI: 10.1038/s41467-024-55675-z).

"You have rock that's hitting at a kilometre per second, maybe 2 kilometres per second, and that can be devastating," says Kring.

The findings will be reassuring for NASA's Artemis III mission to put astronauts on the moon in the region of the south pole, as they indicate the ejected regolith from Schrödinger won't be deep enough in any of the proposed landing spots to seriously hamper geology experiments. If they had been planning to land north of Schrödinger, where far more material landed, then they would have faced an extremely deep layer that masked earlier geology.

"You have rock hitting at 1, maybe 2, kilometres per second, and that can be devastating"

Mark Burchell at the University of Kent, UK, says the research goes some way to prove that the canyons were formed by chains of impacts, but doing so for sure would require collecting rocks from the canyons to see if the structure of minerals in them has changed as a result of the impacts. ▮

Climate change

Rat populations in cities are booming as the planet warms up

IT HAS long been predicted that many pest species will thrive as the planet warms – and now a study of 16 major cities has found that rat populations are growing fastest in areas where average temperatures are rising quickest.

It is very difficult to estimate the number of rats in a city, so Jonathan Richardson at the University of Richmond in Virginia and his colleagues instead got a sense of how populations are changing by looking at the number of complaints about rats recorded by cities.

In the US, this data is often publicly available, and the team was also able to get data for a few places outside the US by contacting city officials. The team only looked at cities if there was at least seven years of data and the methods for collecting it hadn't changed. That left 13 US cities, as well as Tokyo, Amsterdam and Toronto.

The analysis suggests rat numbers are declining in New Orleans, Louisville and Tokyo, are stable in Dallas and St Louis, and are rising in the other 11 cities, with the fastest growth in Washington DC, San Francisco, Toronto, New York and Amsterdam.

The team then looked at what might explain the trends. The strongest link was with the average temperature increase over the past century. The next strongest link was with urbanisation, assessed from satellite photos, followed by human population density. No link was found between the city's GDP and its rat trends

GARY HERSHORN/GETTY IMAGES

New York has one of the fastest growing populations of rats

(*Science Advances*, doi.org/g83r5c).

It is known that in colder cities, rat numbers fall during the winter and peak in summer, so it makes sense that rising temperatures are leading to rising populations, the researchers say.

The findings show that cities need to do more to control rat populations as the planet warms, and cutting off their food supply is the single most important measure, says Richardson. "Securing food waste and making it inaccessible to rats is the approach that will have the biggest impact on controlling rats," he says. ▮

Michael Le Page

Analysis Health

Is recycled plastic in utensils really a big health concern?

A recent scientific paper created alarm around the chemicals in black plastic utensils, but the extent to which they cause harm is up for debate, finds **Chris Simms**

I RECENTLY threw away my trusty black plastic spatula after a scientific paper claimed that such utensils may contain dangerous levels of flame-retardant chemicals. It turns out the researchers had misplaced a decimal point and the concentration of chemicals wasn't nearly as close to safety limits as was originally stated.

Regardless, the work still found some level of fire retardants in 85 per cent of 203 common household items. But how risky is this, if at all, to our health?

Despite the error, the finding was concerning for two reasons. First, flame retardants, particularly ones containing bromine, are associated with health issues, and persist and accumulate in animals and the environment.

The second reason is that these compounds aren't deliberately put in household utensils. They were originally added to black plastics for electronic products because they reduce electronics' chances of overheating, which can cause fires. When these goods are recycled, the compounds get incorporated into new products.

CAVAN IMAGES/GETTY IMAGES

Heating and contact with fats can both cause chemicals to leach from plastics

Chemical contamination

Unwanted chemicals can also sneak in if heating during the recycling process creates new chemicals or if they leach into plastic before it is recycled, according to a 2023 report from Greenpeace.

"You don't know what people are doing with plastic at home," says Bethanie Carney Almroth at the University of Gothenburg in Sweden. "I might put gasoline in a bottle and keep it in a garage, but later throw the container in a recycling bin. Plastics are hydrophobic, so chemicals that aren't very water-soluble will be absorbed into them."

In 2023, Carney Almroth and her colleagues showed that contamination of recycled plastics was a widespread problem. They found hundreds of pollutants, including pesticides and pharmaceuticals, in recycled plastic collected in 13 countries.

Whether people should worry is a harder question to answer. Yes, studies have linked brominated flame retardants to certain conditions, including weak bones and to disruptions to the endocrine system, which releases hormones into the body. But we don't have good-quality evidence that general exposure to these retardants causes problems.

A further issue is the thousands of chemicals in plastics that could be hazardous to human health, but which are often poorly studied. "Only about 1 per cent of the chemicals in plastics are globally regulated, so we don't know if people are exposed to levels that are higher than safety levels," says Carney Almroth.

Yet a recent analysis of 1700 previously published studies, covering about a third of the world's population, linked estimated higher levels of chemicals from plastic found in urine and blood samples to millions of cases of heart disease and thousands of strokes.

Black plastic utensils are often highlighted because there is evidence that they might contain higher levels of heavy metals and flame retardants, but also because of how they are used. "There are certain conditions that would increase chemicals leaching out of plastic into foodstuffs," says Carney Almroth. "Heating is one of them, contact with fats is another."

> **"It would be wise to exclude contaminated plastics from the recycling process"**

This leaching risk is, again, because the chemicals aren't very water-soluble. As well as being more likely to jump from water into plastic, they are more likely to leach out into oils and other fats than into water, says Carney Almroth. Low pH levels can also cause this leaching, meaning that acidic foods such as tomatoes could also increase exposure risk, she says.

Exposure risk

But the distinction between exposure risk and health risk is an important one, says Stuart Harrad at the University of Birmingham, UK, even if you are using a utensil with higher levels of contaminants. "Just because you're exposed to something doesn't mean it's going cause you problems," he says. "Everybody is exposed to these chemicals and this is just one of the ways."

As to whether we should be avoiding recycled plastics, the jury is out. "In food-contact material, yes I would," says Carney Almroth. "In other products, maybe the concern is not as high because the exposure wouldn't be as high."

But Harrad takes a less wary approach. "Clearly, the fact that we're not all dropping dead like flies suggests that it's not going to be the end of civilisation as we know [it]," he says. "I wouldn't at this point be advising people to steer clear of particular plastics, but I would be raising awareness because people are, I think, blissfully ignorant of just how many chemicals we [are] all exposed to."

Recycling plastics must continue for the sake of the planet, he says, but it would be wise to exclude contaminated plastics from the process: "You don't just recycle the plastic; you recycle everything that goes with it as well." ▮

Physics

37-dimension light shows strangeness of quantum physics

Karmela Padavic-Callaghan

PARTICLES of light that effectively exist in 37 dimensions at once have been used to test an extreme version of a quantum paradox.

"This experiment shows that quantum physics is more nonclassical than many of us thought. It could be [that] 100 years after its discovery, we are still only seeing the tip of the iceberg," says Zhenghao Liu at the Technical University of Denmark.

Liu and his colleagues focused on the Greenberger-Horne-Zeilinger (GHZ) paradox, which shows quantum particles can stay connected across large distances for over 30 years. In the simplest version of the paradox, three particles are connected through quantum entanglement, a special link that allows observers to learn something about one particle by interacting with the other two.

If researchers assume the particles can influence each other only when they are in close proximity – in other words, when so-called spooky action at a distance is forbidden – then equations and experiments get snarled in mathematical impossibilities. In fact, the paradox can be expressed through a calculation that results in 1 and -1 being equal, which cannot be true. In the 1990s, physicists realised that the only way to avoid such impossibilities was to accept that particles can participate in quantum spookiness.

Liu and his colleagues wanted to construct the most extreme version of this paradox yet. Specifically, they wanted to find states of photons, or particles of light, whose behaviour in a GHZ experiment would be the most different from that of purely classical particles.

Their calculations revealed that photons had to be in quantum states as intricate as if they existed in 37 dimensions. Just as your position right now must be determined in reference to three spatial and one temporal dimension of our world, each photon's state had to use 37 such references (*Science Advances*, doi.org/n4rz).

> "We produced some of the most nonclassical effects in the quantum world"

The researchers then tested this idea by translating a multidimensional version of the GHZ paradox into a series of pulses of very coherent light – light that is extremely even in its colour and wavelength – which they could then manipulate.

"The state encoded by the light and the measurement on it is governed by the same math underneath the quantum physics. Our experiment can thus produce some of the most nonclassical effects in the quantum world," says Liu.

"This is a result 'for eternity', in the sense that it can be relevant in [a] hundred years," says Otfried Gühne at the University of Siegen in Germany. He says that, beyond probing the limits of quantumness, the new work could also have implications for how quantum states of light and atoms are used for information processing, like in quantum computing.

Liu says this is what he wants to study next as well: how to make computations faster by encoding information into quantum states similar to those his team has already studied. ▮

Zoology

Aerial urine may help dolphins communicate

James Urquhart

MALE Amazon river dolphins have been documented rolling upside down and firing a stream of urine into the air. As if that isn't bizarre enough, other males seek out the urine as it arcs back down to the water, possibly to receive social cues in a similar way to how land mammals use scent marking.

Claryana Araújo-Wang at CetAsia Research Group in Ontario and her colleagues documented the unusual behaviour while studying Amazon river dolphins (*Inia geoffrensis*), or botos, in the Tocantins river in central Brazil.

"On the first occasion, we saw a male flip his belly up out of the water, expose his penis and then proceed to urinate into the air," says Araújo-Wang. "We were really shocked, as it was something we had never seen before."

Araújo-Wang and her colleagues spent around 219 hours observing the dolphins and saw the males fire urine into the air 36 times, with the streams often reaching 1 metre high before landing 1 metre in front of the same animal (*Behavioural Processes*, doi.org/n4rd).

On two-thirds of such occasions, another male was present. This animal would approach, and sometimes pursue, the urine stream with its snout. Other times, it would wait in the area where the stream of urine landed in the water.

The researchers' best guess to explain this behaviour is that bristles on the dolphin's snout might act as chemical sensors to detect urine and interpret social cues. Hormones in urine might signal a male's quality, in terms of social position or physical condition, says Araújo-Wang.

A 2022 study by Jason Bruck at Stephen F. Austin State University in Texas and his colleagues found that bottlenose dolphins (*Tursiops truncatus*) can use their tongues to identify individuals underwater by the taste of their urine.

If something similar is happening with the Amazon river dolphins, it is unclear why they fire urine into the air instead of directly into the water. Bruck speculates that as the dolphins' vision is poor, the sound of the urine hitting the water could be an acoustic signal to let them know where the urine is.

"We still don't know what other information can be gleaned from urine, including sex or reproductive status," he says. ▮

CLARYANA ARAÚJO-WANG/BOTOS DO CERRADO RESEARCH PROJECT/CETASIA RESEARCH GROUP

Male Amazon river dolphins like to sense other males' urine

Mental health

Creatine may help treat depression

The supplement showed promise alongside talking therapy for mild to severe depression

Carissa Wong

A DAILY dose of creatine while undergoing talking therapy seems to ease depression, with minimal side effects.

Creatine is a compound that is naturally produced by our bodies and is found in protein-rich animal products. It helps supply energy to cells, so it is best known as a bodybuilding supplement, but it is increasingly being linked to multiple health benefits.

For instance, scientists have previously shown that it may enhance the effects of antidepressant drugs, but it was unclear whether creatine can benefit people with depression who are receiving cognitive behavioural therapy (CBT), which can help people manage their problems by changing the way they think and behave.

To look into this, Riccardo De Giorgi at the University of Oxford and his colleagues recruited 100 people in India with mild to severe depression. At the start of the study, the participants took a survey that is commonly used to screen for the severity of depressive symptoms, on which they scored an average of 17.7 on a 27-point scale. The average age of the individuals was 30 and it had been at least eight weeks since any had taken antidepressants.

> "Creatine seems to give a level of benefit that's large relative to the very low risks"

The team then split the participants into two groups, half of whom took a daily creatine pill alongside CBT sessions every two weeks for eight weeks, while the rest had the same talking therapy but were given a placebo pill.

By the end of the study, some participants had dropped out, leaving 30 people in each group. When completing the same survey as they did at the start, those who had taken creatine scored 5.8 on average, which is considered mild depression. The placebo group scored 11.9, corresponding to moderate depression (*European Neuropsychopharmacology*, doi.org/n4k6).

"That's actually a very, very large effect of creatine," says Brent Kious at the University of Utah. "Definitely an effect that a patient would notice in terms of well-being."

Side effects were also mild and similar between the two groups. "It seems to give a level of benefit that's large relative to the very low risks," he says.

Creatine may partly work by bolstering energy supplies in brain regions involved in depression, such as those that regulate emotions, says Kious. "It could basically be building a better battery for the brain."

The compound's activity outside of the brain may also contribute to its antidepressive effects. "There might be a peripheral action that makes you feel better, more physically strong, and maybe that can feed into improving overall well-being," says Philip Cowen, also at the University of Oxford.

Future research should explore this, but larger studies that involve more ethnically diverse people in multiple countries are needed first to confirm the results of the trial, he says.

"Things like diet and lifestyle factors might affect people's normal creatine intake, and so the effects of supplementing it," says Cowen.

Studies should also explore creatine's long-term effects, says De Giorgi. "One of the problems with all antidepressant strategies is that people do tend to relapse, so it would be interesting to see what happens in the long term." ▮

Climate change

Surge in ocean heat hints climate change is accelerating

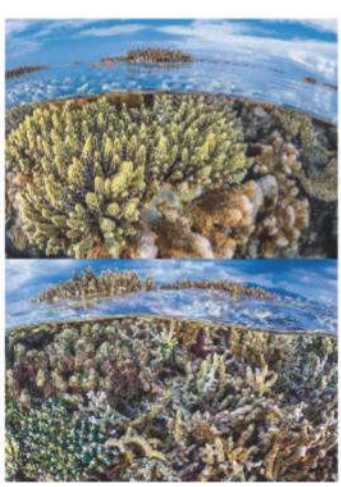
THE rise in ocean temperatures to record-breaking levels in 2023 and 2024 is a sign that the pace of climate change has accelerated, say researchers.

Global ocean temperatures hit record highs for 450 days straight in 2023 and early 2024. Although some of the extra heat can be explained by an El Niño weather pattern emerging in the Pacific Ocean, about 44 per cent of the record warmth is down to the world's oceans absorbing heat from the sun at an accelerating rate, according to Chris Merchant at the University of Reading, UK.

Merchant and his colleagues used satellite data to analyse ocean warming over the past four decades, concluding that the rate of warming has more than quadrupled since 1985 (*Environmental Research Letters*, doi.org/g829n5).

The team says this rapid acceleration is down to a sharp change in Earth's energy imbalance (EEI), a measure of how much heat is being trapped in the atmosphere. EEI has roughly doubled since 2010, causing the oceans to soak up much more heat now than they used to.

"The oceans set the pace for global warming in general," says Merchant. "So, as an extension, global warming as a whole, including the land, has therefore accelerated." He says he is "personally convinced" that accelerating climate change was a major factor in the recent surge in ocean temperatures.



BIOSPHOTO/ALAMY

Coral off the island of Mayotte in the Indian Ocean in 2023 (top) and in 2024 (bottom) following bleaching due to warmer waters from El Niño

The team predicts that the rate of ocean warming could continue to increase rapidly in the coming decades. "If the EEI trend extrapolates into the future… then we can expect as much warming in the next 20 years as we have had in the last 40 years," says Merchant.

Climate models do expect the rate of climate change to accelerate, but Merchant's analysis suggests real-world trends are in line with the most pessimistic outcomes. However, early data suggests that EEI dropped in 2024 after a record spike in 2023. This might mean warming rates aren't accelerating in line with worst-case scenarios. ▮

Madeleine Cuff

Computing

Quantum-inspired algorithm could give us better weather forecasts

Matthew Sparkes

YUICHI YAMAZAKI/AFP VIA GETTY IMAGES

Air turbulence can lead to rain, but is hard to simulate

ALGORITHMS inspired by quantum computing can simulate turbulent fluid flows on a classical computer much faster than existing tools, slashing computation times from several days on a large supercomputer to just hours on a regular laptop. This could be used to improve weather forecasts.

Turbulence in liquid or air involves numerous interacting eddies that quickly become so chaotically complex that precise simulation is impossible for even the most powerful classical computers. Quantum computers promise to improve matters, but currently even the most advanced such machines are incapable of anything but rudimentary demonstrations.

Simulations of turbulence can be simplified by replacing precise calculations with probabilities. But even this approximation leaves scientists with computations that are infeasibly demanding to solve.

Nikita Gourianov at the University of Oxford and his colleagues have developed a new way to represent turbulence probability distributions that uses quantum computer-inspired algorithms called tensor networks. This could allow us to eke out more performance from existing classical computers before truly useful quantum machines are available.

"The algorithms and the way of thinking comes from the world of quantum simulation, and these algorithms are very close to what quantum computers do,"

"This could let us eke out more performance from computers before useful quantum ones arrive"

says Gourianov. "We're seeing quite a drastic speed-up, both in theory and in practice."

Using them, the team was able to run a simulation on a laptop in just a few hours that previously took several days on a supercomputer. The new algorithm saw a 1000-fold reduction in processor demand, and a million-fold reduction in memory demand (*Science Advances*, doi.org/n4pc).

While this simulation was just a simple test, the same types of problems on a larger scale lie behind weather forecasts, aerodynamic analysis of aircraft and analysis of industrial chemical processes.

The turbulence problem, which involves five dimensions of data, gets extremely difficult without using tensors, says Gunnar Möller at the University of Kent, UK. "Computationally, it's a nightmare," he says. "You could maybe do it in limited cases, when you have a supercomputer and are happy to run it for a month or two."

Tensor networks work, in effect, by reducing the amount of data a simulation requires, drastically cutting the computational power required to run it. The amount and nature of the data removed can be carefully controlled by dialling the level of precision up or down.

Large and fault-tolerant quantum computers, once they are created, will be able to run tensors on a much larger scale and with much greater precision than classical computers, but Möller says he is excited by what might be achieved in the meantime with conventional devices.

"With a laptop, the authors of this paper could beat what's possible on a supercomputer, just because they have a smarter algorithm. It immediately has a tremendous benefit, and I don't have to wait another 10 years to have the perfect quantum computer," he says. ▮

Physiology

Scratching an itch could help boost immune defences

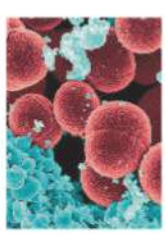
Chris Simms

FORGET what your parents told you, scratching an itch may be good for you, by boosting your body's defence against bacteria.

It can feel nice to run your nails over an itch, which hints there is an evolutionary reason we get pleasure from scratching, and yet it can also aggravate conditions like eczema.

To dig into this dichotomy, Dan Kaplan at the University of Pittsburgh in Pennsylvania and his colleagues induced eczema-like symptoms on mice's ears. The ears of mice that could scratch at will contained more neutrophils – cells that help fight infection – than those wearing a collar that stopped them from reaching their ears.

When the researchers took a closer look, they found that scratching made pain-detecting neurons release a chemical known as substance P. This then activated



PHANIE/SIPA PRESS/ALAMY

Staphylococcus aureus bacteria (red) live on the skin

white blood cells called mast cells, encouraging the production of more neutrophils (*Science*, doi.org/g83n55).

"It shows that the act of scratching is really important in augmenting mast cell behaviour," says Holly Wilkinson at the University of Hull, UK.

The team also found that scratching reduced the amount of *Staphylococcus aureus*, a bacterium commonly involved in skin infections, on the mice's skin.

"If you're basically healthy and scratching, it is a good thing," says Wilkinson. "But if you are scratching too much then it could become a negative thing." ▮

Analysis Genetic engineering

Mice with two dads born – but don't expect the same for people

For the first time, mice with two fathers have survived to adulthood, but trying the same method in people would be "unthinkable", finds **Michael Le Page**

MICE whose genetic parents are both male have survived to adulthood for the first time. However, achieving this required extensive genetic modification, among other things, that could never be attempted in people.

These aren't the first mammals with same-sex parents – mice with two mothers were first created in 2004, and while unusually small, they appeared to live longer than normal. But creating mice with two fathers has proved to be more difficult.

Nonetheless, in 2018, a team led by Zhi-kun Li at the Chinese Academy of Sciences in Beijing reported the birth of 12 mice with two fathers, although they weren't healthy and none survived to adulthood. Now, the same team has managed to create such mice that did survive into adulthood, although they didn't live as long as normal and couldn't have offspring of their own (*Cell Stem Cell*, doi.org/g83d5x).

ZHIKUN LI

A mouse with two fathers (left) and a control mouse (right) of the same age

Imprinting problem

These researchers might not be the only ones to have achieved this. In 2023, a team in Japan announced the birth of seven apparently healthy mice with two fathers, but we don't know if these survived until adulthood.

So why is it so difficult to create mammals with two fathers? And is there any way we could one day do this in humans, so two men could have children that are a genetic mix of both of them?

The answer to the first question lies in a phenomenon called imprinting. The DNA in cells contains recipes, or genes, for making key molecules. But you don't want, say, muscle proteins being made in a brain cell, so as cells develop into specialised types, unneeded genes get switched off, or silenced.

One way cells do this is to add chemical labels to DNA. If you think of the genome as a recipe book, these labels are like sticky notes saying: "Don't make this recipe." They can be added and removed in a so-called epigenetic change, in other words without altering the underlying DNA.

This process also occurs in sperm and eggs. However, crucially, the genes that get silenced in sperm are different to those silenced in eggs, and the distinct pattern of genomic activation/deactivation in these cells is what we call imprinting. So if you simply put the DNA from two males – or two females – together in an embryo, it won't develop normally because some genes that should be active are silenced and vice versa.

Why does imprinting happen? It is thought to be a result of an evolutionary battle between the sexes. Males turn off genes that limit the growth of their offspring, but offspring that grow too large before birth can harm females, so females turn off genes that boost fetal growth at their expense.

To create animals with same-sex parents, the male/female imprinting patterns have to be recreated. Mimicking the female pattern requires more changes than mimicking the male pattern, so it is harder to create mammals with two fathers than two mothers.

Katsuhiko Hayashi at Kyushu University, who led the 2023 study in Japan, did this by finding male cells that had naturally lost the Y chromosome and generating eggs from them – thus resetting the imprinting to that in eggs – and then fertilising them with sperm.

20

Number of genes disabled in order to create mice with two fathers

As a result, Hayashi revealed the birth of seven apparently healthy mice. *New Scientist* has asked him if any survived to adulthood, but hadn't received a reply at the time of writing.

Li has instead been genetically modifying mice to disable genes that are normally imprinted – the equivalent of tearing pages out of the recipe book rather than adding sticky notes.

To get two-father, or bipaternal, mice to survive to adulthood, his team had to disable 20 genes – compared with three for mice with two mothers – and even this isn't enough. "It is fair to say that these mice were not completely healthy," says Li. "It is likely that [disabling] additional imprinted genes, beyond the 20 we targeted, could contribute to improving the health of these mice."

Battle of the sexes

Generating the mice also involved making embryos from eggs and collecting embryonic stem cells from them on multiple occasions.

"At present, it is unthinkable to translate [Li's] method of generating bipaternal animals from mice to humans," says Christophe Galichet at the Sainsbury Wellcome Centre in the UK. But the results are still valuable, he says.

For one thing, they support the idea that imprinting is the result of a battle between the sexes. Li's team found that the bipaternal mice grew especially fast and had abnormalities related to organs growing too big.

But if the aim is to allow two men to have genetic children of their own, with the help of a surrogate mother, Hayashi's approach is more promising, as it can be carried out without genetic modification.

However, key steps in his process can't yet be done in people, so we are still a very, very long way from creating children with two genetic fathers. ▮

Physics

Quantum spookiness illuminated

Twisted light reveals secrets of quantum entanglement's "spooky action at a distance"

Karmela Padavic-Callaghan

QUANTUM light has shown that the "spookiness" that can inextricably link two distant particles can be equivalent to an equally odd property of just one.

"The quantum world operates in ways that are fundamentally different from the familiar, deterministic laws of classical physics," says Jianqi Sheng at Xiamen University in China. He and his colleagues studied two prime examples of strange quantum behaviour, known as contextuality and nonlocality.

Contextuality means that the result of a measurement of a quantum object depends on which other measurements are being made on it at the same time. Think of soup – what a bean in a broth tastes like depends on the other ingredients alongside it. Nonlocality means that measuring the properties of one quantum object, like a particle, can immediately reveal something about another one, even when it is very distant. This entanglement is sometimes called "spooky action at a distance", and researchers disagree on how it happens.

Strikingly, Sheng and his colleagues have now shown that one of these properties can be converted into the other.

They used entangled pairs of particles of light, or photons. The researchers put each photon in a quantum state that had intricate rotational properties: had they been part of a beam of light, that beam would have been twisted in the shape of a helix.

The more twisty they made the photons, the more intricate their quantum states got. In fact, they could create photons whose quantum states had up to six dimensions, behaving as if they existed in a six-dimensional quantum world. You could say that the soup had many layers of flavour.

Because the photons were entangled, the researchers knew the particles would experience nonlocality. For instance, making one of them travel through a lens, which changed its properties, always meant that they immediately knew the corresponding new properties of the other photon without having to measure it.

"The more twisty the researchers made the photons, the more intricate the quantum states got"

To connect this with contextuality, the researchers used a mathematical recipe for converting between nonlocality and contextuality that was developed by Adán Cabello at the University of Seville in Spain. When they plugged their measurements into a formula to check whether the conversion worked, they found that it did (*Physical Review Letters*, doi.org/n4kn).

Entanglement can also be multidimensional, so Sheng says that being able to put photons into multidimensional states lets them share many correlations with their partner, which was key in making this test unambiguous.

"When I started [studying] all this stuff many years ago, these experiments were dreams," says Cabello. "The experiment really matches the quantum prediction. It is an extremely beautiful confirmation that nature is really following quantum mechanics to an incredible degree of precision." ▮

Technology

XB-1 aircraft goes supersonic for the first time

THE experimental XB-1 aircraft, made by US company Boom Supersonic, flew faster than the speed of sound on 28 January. The achievement is a step towards the possible return of supersonic commercial aviation.

"This jet really does have a lot of the enabling technologies that are going to enable us to build a supersonic airliner for the masses," said Greg Krauland, former chief engineer for Boom Supersonic, during a live stream of the test flight.

At the Mojave Air & Space Port in California, Boom Supersonic's chief test pilot Tristan "Geppetto" Brandenburg took the XB-1 on its first supersonic test flight. The sleek white prototype, with a blue-and-yellow tail assembly, broke the sound barrier on the first pass in the test airspace, reaching a speed of about Mach 1.11. Brandenburg did two more supersonic runs before returning to land.

The only aircraft currently able to reach supersonic speeds are military fighter jets and bombers. Although the commercial airliner Concorde made transatlantic supersonic flights, it retired in 2003 due to multiple challenges, including high fuel costs and an accident in 2000 that killed everyone on board.

The success of the XB-1 could herald a return for supersonic commercial flight. The test flights are meant to inform the design of a planned Overture airliner that Boom Supersonic says would cruise at Mach 1.7 and carry up to 80 passengers. The company plans to start producing these airliners this year and begin carrying passengers on them in 2029 – and airlines like United and American have already placed orders.

BOOM SUPERSONIC

The XB-1 aircraft flew at supersonic speeds over California

Other supersonic aircraft are also in the works, including from NASA. The agency's experimental X-59 is designed to minimise the shock wave that normally accompanies supersonic flight in order to create a sonic thump rather than a sonic boom. ▮

Jeremy Hsu

Zoology

How polar bears stop ice from freezing on their fur

Michael Le Page

POLAR bears have a hidden-in-plain-sight superpower that anyone who has watched a wildlife documentary could have spotted: ice doesn't stick to their fur.

This has long been known to Indigenous peoples of the Arctic, who have utilised this property of the fur, but only now has it been noticed and studied by scientists. Bodil Holst at the University of Bergen in Norway and her colleagues have shown that the ice resistance of polar bear fur is due to natural oils secreted onto the hairs, rather than a property of the fur itself.

Holst is a physicist who studies the properties of surfaces. Her interest in polar bear fur began when, while watching a TV quiz programme, she saw that the bears hardly show up on infrared cameras because they are so well insulated. That means the temperature of their outer fur is below freezing, Holst realised, but she had never seen a polar bear in wildlife films that was coated with ice, even after swimming in sub-zero waters.

"And then I thought, well, how come freezing is not a problem? How come you don't get accumulation of ice on the fur under these circumstances?" she says.

This is, after all, a problem for many other land mammals in cold environments, such as musk oxen. Holst asked researchers at the Norwegian Polar Institute if they knew why polar bear fur doesn't ice up. None did, but they decided to investigate together.

Holst and her colleagues obtained samples of polar bear fur from Svalbard in Norway and compared them with human hair. They found that the force required to remove ice from polar bear hair was a quarter of what was needed for human hair – meaning the bears can easily shake any ice off.

STEVEN KAZLOWSKI/NATURE PICTURE LIBRARY/ALAMY

You will never see a polar bear covered in ice, even after swimming

Washing polar bear fur removed its ice resistance, suggesting that the oily coating on the hairs is the key to its properties (*Science Advances*, doi.org/g83j4g). This substance, known as sebum, is secreted by glands connected to hair follicles.

"Accumulation of ice on fur is a problem for land mammals like musk oxen, but not polar bears"

Polar bear sebum lacks a substance called squalene that is commonly found in sebum, especially in aquatic mammals, the team found. It also contains some unusual fatty acids. These could be unique to polar bears, but we can't be sure of that, as so few studies have looked at the composition of animal sebum, says Holst.

Arctic peoples such as the Inuit have traditionally prepared polar bear fur in a way that preserves the sebum, unlike methods used for other furs. They have also used the fur in ways that make use of its ice-resistant properties.

For instance, Inuit hunters in Greenland are known to have placed small pieces of polar bear fur under the legs of the stools used by hunters, to stop them sticking to ice. They also strapped polar bear fur to the soles of boots while stalking animals, to avoid the noise made by ice-coated surfaces.

Holst's team is now exploring potential applications, such as creating environmentally friendly ski waxes that don't contain the long-lasting fluorocarbon compounds currently used to prevent icing.

A hair wax based on polar bear sebum could also help people who work in cold environments. "I had not thought about that application, but absolutely, that should work," says Holst. "I think you've just given me a new idea." ▮

Health

Muscle patch made from stem cells could treat heart failure

Grace Wade

A PATCH of muscle grown from stem cells has improved cardiac function in monkeys with heart disease. It is now being tested in a small number of people, with early results from the first recipient suggesting it could treat advanced heart failure.

Heart failure usually occurs after a heart attack permanently damages or weakens the organ. Short of receiving a transplant or fitting a pump, no treatment can fully restore cardiac function.

Wolfram-Hubertus Zimmermann at the University of Göttingen in Germany and his colleagues made heart muscle and connective tissue cells using pluripotent stem cells, which can transform into any cell type. These cells were then cultivated in a hydrogel mould for 28 days to create a 4-centimetre-by-4-centimetre patch, which contracts like heart muscle.

The researchers surgically implanted the patches over damaged and scarred areas of the heart in six monkeys with chronic heart failure. Half received two patches while the rest received five.

After six months, those with five patches had, on average, a more than 7 per cent increase in the amount of blood that their hearts could pump around the body with each beat. This measure declined by roughly 2.5 per cent in a separate group of seven monkeys that didn't receive a patch, and there were no changes in those with two patches (*Nature*, doi.org/g83j3f).

The patches have already been implanted in 15 people with advanced heart failure. When one person received a heart transplant three months after getting the patch, it gave the researchers a chance to examine the excised heart. They found the patch's cells had survived and integrated without side effects. Zimmermann expects data from the other participants by the end of the year. ▮

Environment

Tree scars reveal how wildfires in centuries past differed from today

Taylor Mitchell Brown

SCARS on trees left by fires hundreds of years ago are helping scientists understand past wildfire trends across North America and giving clues to how blazes might unfold with further climate change.

Fire scars are small wounds made when fires burn near trees but don't kill them. They provide rich details about past wildfires and their underlying causes, says Chris Guiterman at the University of Colorado, Boulder.

"For dendrochronologists examining fire scars, every tree and every site tells a story about the past forest – its age, how climate influenced its growth and productivity, how fire spread through and influenced the forest and how people augmented or disrupted its function," he says.

Guiterman and his colleagues studied a database of fire scars in North America that was established in 2022 to enable scientists to learn about past forest fires using physical data stored in trees. Most of the trees in this database have around six fire scars.

The researchers focused specifically on scars from 1750 to 1880. This window precedes widespread industrialisation and the modern era of forest fires.

Results showed that many areas that experience severe wildfires today, including western parts of Canada and the US, had frequent, widespread fires over 150 years ago (*Global Ecology and Biogeography*, doi.org/n4k5).

A giant sequoia with a burn scar following a wildfire in 2021

ERIC PAUL ZAMORA/AFP VIA GETTY IMAGES

Like those of today, pre-modern fires were influenced by many factors, including climate, vegetation and people, says Guiterman. Soil moisture and fire scar data revealed a particularly clear connection between periods of drought and subsequent fires.

Most pre-modern fires were significantly less severe than those today. Then, beginning in the 20th century, forest fires were largely suppressed across North America. This created a surplus of vegetative fuels that, in turn, increased fire size and severity.

"Had historical fire regimes continued to present, modern fires – even under 'extreme' conditions – would likely be quite manageable and beneficial to forests," says Guiterman. The study serves as a reminder that fires were common and extensive following drought, and we can expect to see more severe droughts as a result of climate change, he says.

"When fire activity is synchronised by regional drought, firefighting resources are quickly spread too thin and exhausted," says Tom Swetnam at the University of Arizona. "The overall findings highlight the danger of extreme fire occurrence years, especially in western North America."

Guiterman worries that fire-scarred trees, stumps and logs will eventually disappear from our forests, so thinks they should be collected and studied now.

"The urgency is huge, because people, climate and fire are removing, degrading and burning the evidence of past fire regimes, and we still have so much more to learn," he says.

Physiology

'Obsolete' ear muscle may be helping us listen

A "USELESS" muscle that allows some people to wiggle their ears actually activates when we strain to hear something.

Our ape ancestors lost the ability to pivot their ears when they diverged from monkeys millions of years ago, but some of the muscles and brain neurons that underpin this trait remain in humans today.

Many scientists have assumed that these so-called auricular muscles are obsolete, even if they do enable ear wiggling. But in 2020, Daniel Strauss at Saarland University in Germany and his colleagues found that they become activated in response to hearing sounds from different directions, prompting them to wonder whether this also happens when people are concentrating on listening.

To explore this, the researchers got 20 people with typical hearing to take three listening tests of varying difficulty. They all involved focusing on a 5-minute audiobook clip narrated by a female voice while skin sensors measured electrical activity in their auricular muscles.

In an easy test, the researchers quietly played a podcast hosted by a male voice at the same time as the audiobook. In a medium-difficulty task, they added a quiet clip of a female voice – similar to the one in the audiobook – to the setup. In the hardest test, both background clips were made louder.

The researchers discovered that the largest auricular muscle, the superior auricular muscle, became most activated during the trickiest test (*Frontiers in Neuroscience*, doi.org/n4n9). "It's pretty amazing to see this nearly forgotten muscle working so hard during effortful listening," says Strauss.

"It's pretty amazing to see this nearly forgotten muscle working so hard during effortful listening"

The team didn't assess if this assisted the participants' ability to focus on the main audiobook, but measuring its activity could provide an objective way to assess listening effort. This could help develop better hearing aids, which aim to minimise listening strain, says Strauss.

Carissa Wong

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Views

The columnist Annalee Newitz on the legacy of futurism p22

Aperture Prize-winning photos capture Earth's vanishing ice p24

Culture Inside the high-stakes hunt to collect meteorites p26

Culture column Emily H. Wilson looks at new sci-fi novel *Shroud* p28

Letters The problem with talk of a 1.5°C climate goal p29

Comment

The truth is out there

Increasing numbers of people believe Earth has probably been visited by aliens. That's a societal problem, says **Tony Milligan**

ABOUT a fifth of the UK's population now believes Earth has probably been visited by aliens. "Probably" is not "certainly", but the number is still high. It is higher still in the US, where belief in UFOs has risen from 34 per cent in 2007 to 42 per cent in 2023. This is a real shift – and a societal problem.

Odd ideas such as fortune telling and belief in ghosts have always had some currency. But such sympathies tend to be offshoots of religious traditions involving the supernatural, and have little connection to shifting political trends.

By contrast, the growth of belief in alien visitation has been driven by a populist wave in US and European politics, now well into its second decade. Typical targets of populism include a secretive billionaire elite, the political establishment and the military, who have subverted democracy and kept the truth from the people. Truth about covid-19, vaccines and aliens. Truth that the scientific establishment is too narrow-minded to consider or else incentivised to conceal. This, at least, is the populist narrative. While its primary target is elites, it also tends to be hostile towards scientific authority.

The comparative success of populist versions of ufology also owe something to their tolerance of ambiguity. Survey questions don't focus on abduction, crop circles or the 1947 retrieval of alien bodies at Roswell, New Mexico.

ELAINE KNOX

Often, questions are framed in the language of "probably". Believers can simply accept that governments and elites are hiding something: they "probably" know more about UFOs and aliens than they are willing to reveal.

While the surveys may track ambiguous belief, ufology's breakthrough into mainstream political discussion was fueled by a 2017 *New York Times* article detailing five years of US government funding, to the tune of $22 million, for the Advanced Aerospace Threat Identification Program. It's an official-sounding title for a revamped fringe investigation body, repurposed to search for UFOs and to evaluate any threat they might pose.

Two of the three authors of the exposé were established believers. Ralph Blumenthal has appeared at the UK's popular annual Exeter UFO Festival and on the *Ancient Aliens* TV series. Leslie Kean had already written a book on UFOs and the military in 2010. Their main source, Luis Elizondo, was a former US intelligence officer who provided a now-infamous set of grainy videos that will look suspicious to anyone unfamiliar with forward-looking infrared images.

The videos went viral and inspired another ex-intelligence officer, David Grusch, who joined a US military-supported investigative body set up to look into "Unidentified Aerial Phenomena". Grusch testified to the US Congress in 2023 about secretive committees and covertly funded UFO investigations. Only occasionally did he slip into more old-fashioned ufology claims about covert programmes to recover the bodies of aliens.

While Grusch and Elizondo fit the mould of traditional ufologists, it isn't obvious that surveys are tracking a rise in similarly fervent beliefs. But if they are merely detecting something softer and more ambiguous, why is it a source of concern? The philosophical answer is that mainstreaming belief in UFOs erodes evidence standards within the public discourse.

The more straightforward answer is that soft believers are a pool from which more conspiratorial hardcore ufologists will emerge, ready to lump science and elites together as enemies of the people. And hardcore ufologists aren't simply looking for alien life – they are looking for conspirators in the laboratory and at the heart of government. ▮

Tony Milligan is a research fellow in ethics at King's College London, focusing on space ethics

This changes everything

Life in the fast lane

The term "futurism" was coined in 1909 and went on to take an abrupt right turn. This way of thinking about the future still influences us today, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest book is *Stories Are Weapons: Psychological warfare and the American mind.* They are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is techsploitation.com

Annalee's week

What I'm reading
Marion Gibson's Witchcraft: A history in 13 trials*, which reminds us that some women hired lawyers and won their witch trials.*

What I'm watching
The Commute*, about the daily migration of thousands of crows in Vancouver, Canada.*

What I'm working on
Getting to know Vancouver better by riding the SkyTrain.

This column appears monthly. Up next week: Rowan Hooper

THE word "futurism" was born in a car crash. At least, that is the story that poet Filippo Tommaso Marinetti told back in 1909, when he coined the term in an editorial for French newspaper *Le Figaro*. He and some friends had spent a wild night drinking and arguing about art when they decided to hop into Marinetti's 1908 Fiat and speed down an Italian road. Startled by two cyclists, Marinetti lost control of the car and flipped it over into a ditch.

In his editorial, which he called "The Futurist Manifesto", Marinetti made the startling claim that the crash was fun. There was the thrill of feeling a big, magnificent machine "hurtling at breakneck speed along the racetrack of [Earth's] orbit". But more important was his joy in the car's violent destruction. This latter feeling, he wrote, was the essence of futurism.

In my column last month, I described how ancient humans understood the future. Now, we are zooming forwards into the modern world, where futurism took an abrupt right turn.

Marinetti argued that a truly "modern man" had to embrace aggression and "glorify war – the sole cleanser of the world", as well as "militarism, patriotism" and total civilisational destruction. War was the only way to abolish the "stinking canker" of history, he wrote, and embrace the technologies of tomorrow.

Perhaps it will come as no surprise that when Marinetti got bored with futurism a decade later, he co-wrote another op-ed, "The Fascist Manifesto". This work inspired Benito Mussolini, Italy's fascist dictator.

Despite his extreme rightward swerve into politics, however, Marinetti's work still influences Western ideas of the future today. Rose Eveleth, creator of the futurist podcast *Flash Forward*, wrote in *Wired* that Silicon Valley leaders often echo Marinetti's futurist manifesto in their rhetoric. Indeed, venture capitalist Marc Andreessen cites Marinetti in his widely-read "Techno-Optimist Manifesto", where he argues that unfettered technological development is the only path towards a better future.

But Marinetti wasn't interested in technology for its own sake. He loved the crash more than the car. For him, technology was wedded to war, which destroyed all in its path to make way for the new. His futurist manifesto anticipated the military-industrial complex of the cold war period, as well as today's high-tech defence firms like drone maker Anduril and surveillance-tech giant Palantir.

"I always shudder when I hear Mark Zuckerberg's Facebook motto: 'Move fast and break things'"

Why did futurists decide that sophisticated war machines represented progress? Marinetti's own life offers a clue. He spent his entire childhood in Egypt, where his father was a lawyer who worked with European colonial businesses to "modernise" the country.

Thus Marinetti's first exposure to futuristic social change was inextricably tied to imperialism, a system of economic development shot through with violence and oppression. Colonisers in Egypt and elsewhere were also very keen to chuck the past away, replacing local history and knowledge with their own.

It is little wonder young Marinetti saw the future as a car crash that snuffed out what had gone before.

And yet, Marinetti would argue, the crash also produces better cars. Ultimately his ideas caught on because so many people in the 20th century were eyewitnesses to the deadly innovations of war and colonialism. The idea of futurism we have inherited from that era isn't just about embracing new tech. It is about how to develop technology, using violence and historical amnesia. This is why I always shudder when I hear Mark Zuckerberg's Facebook motto: "Move fast and break things."

The problem with this approach to the future is that the things you break and forget always return with a vengeance. Colonised people revolt. Dead automobiles poison the environment. There are always steep costs when the future is purchased by liquidating the past.

Perhaps this is why many of the ideas proposed by futurists in 1909 sound like they were ripped from ancient Roman speeches about war and nationhood, rather than being about something genuinely novel, like renewable energy, universal education or sustainable building materials.

Marinetti's brand of futurism has reached its apotheosis in today's AI bubble. The large language models that power products such as ChatGPT are allegedly futuristic tech that will nuke our current economy from orbit. And yet they are fed entirely on historical datasets, so they can never produce anything truly new or original. The faster we go, the more we mire ourselves in the wreckage of our past.

Tune in next month, when I'll talk about how communications technology fuelled 21st-century ideas about what comes next.

Events

NewScientist

Instant Expert

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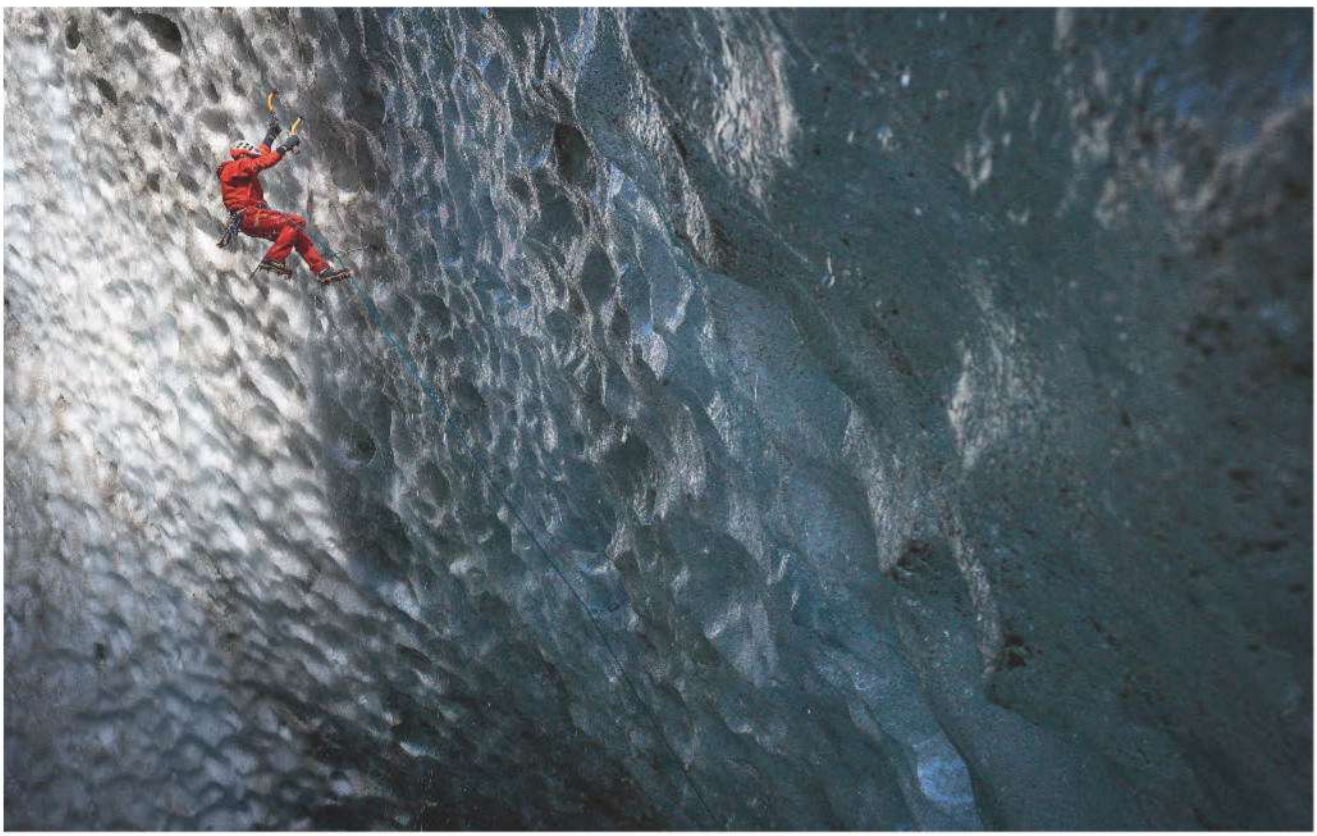

JULIA ROGER-VEYER/ONEWATER

MICHELLE LAPINI/ONEWATER

JULIA ROGER-VEYER/ONEWATER

Meltdown

Onewater
Walk of Water competition

THESE striking images highlight Earth's vanishing ice and the fight to save it. A staggering two-thirds of glaciers may disappear by the end of the century, threatening ecosystems and global water supplies. The images took some of the top prizes in the Walk of Water competition, run by UNESCO and Onewater. UNESCO has designated 2025 as the International Year of Glacier Preservation.

Julia Roger-Veyer received second place in the European category for her atmospheric shots of the Mer de Glace, France's largest glacier, at Chamonix. The near-left image was shot from within a moulin, a huge hole carved into the glacier by meltwater, while the photo in the upper far-left peers inside a cave created by glacial retreat. Roger-Veyer climbs and photographs the Mer de Glace each autumn. Each year, the glacier retreats roughly 40 metres. In an announcement about her win, she said she expects she will "probably be a helpless witness" to its disappearance.

Michele Lapini captured first prize in the Europe category for his shot documenting the effort to save Presena Glacier in northern Italy (bottom, far left). Vital to the alpine ecosystem, the glacier's surface area decreased from 68 hectares to 41 between 1993 and 2003, according to Lapini.

In 2008, conservationists began spreading textile sheets over the glacier each summer to prevent melt. The photo shows a worker unhooking sheets during autumn before the first snow. The effort may have reduced ice melt by two-thirds, but cannot pause ice loss. As Lapini writes, "climate change cannot be mitigated through localized quick fixes alone".

Liz Else

Why space rocks are hot

Hunting for meteorites can be a thrilling, high-octane business as private collectors and scientists go head-to-head, finds **Chris Simms**

Book
The Meteorite Hunters
Joshua Howgego
Oneworld (UK, on sale now; US, 13 May)

STOCKTREK IMAGES, INC./ALAMY; BELOW: STEVE JURVETSON/WIKIMEDIA

Above: A bolide (bright) meteor, in remote Canada. Below: The Imilac meteorite was found in Chile's Atacama desert

ONE evening in July last year, a couple from Prince Edward Island in Canada returned home after walking their dogs to find grey, dusty debris near their door. At first, they thought something had fallen off the roof, but the footage from their doorbell camera revealed something different. They'd had a lucky escape.

While they were out, a space rock – thought to have been somewhere between the size of a golf ball and a baseball and travelling at many thousands of kilometres an hour – had struck the place where they had been standing not long before, with a crash and a noise like shattering glass. Their camera recording, widely publicised in January after the meteorite was officially registered, is believed to represent the first time the complete sound of a meteorite hitting Earth has been recorded on video.

This landmark might give you the impression that meteorite strikes are very rare, but they are quite common. Amazingly, NASA estimates that about 44 tonnes of meteorite material hits Earth each day. Yet these treasures can be hard to find, as we discover in Joshua Howgego's book, *The Meteorite Hunters: On the trail of extraterrestrial treasures and the secrets inside them*. They are well worth the effort, however, because as well as containing a wealth of scientific information, they can be very valuable on the open market.

The first half of the book tells the stories of the people driven to hunt these often-blackened rocks that fell from space. As you might expect from a *New Scientist* editor, Howgego is an expert guide, taking us across deserts, fields and vast expanses of ice as he introduces a motley crew of hunters and collectors, united by passion but divided by competition.

There's "the Space Cowboy", Stetson-sporting private meteorite hunter Robert Ward, and Birger Schmitz, who used to get down on his hands and knees in train stations and airports to examine stone floors. We also meet James Karner, who got into the meteorite hunting game because he loved looking for lost golf balls. And let's not forget the enthusiastic Jon Larsen, who scrapes layers of dust from Oslo's rooftops, sifting through it all to reveal micrometeorites – tiny meteorites that may be sitting on your roof or in your gutters right now. What happened when Howgego and Larsen removed rubbish bags full of the dust from a rooftop about four storeys high made me laugh out loud. But no spoilers here.

Occasionally, the chase sounds like an Indiana Jones movie, as rival hunters struggle to get to the prize first. The competition is fuelled by the thousands people will pay for pieces of meteorites: even a doghouse hit by a meteorite sold for $44,000 at a Christie's auction in 2022. If a private hunter claims a meteorite and doesn't treat it correctly, they can destroy scientific evidence.

Another highlight was reading about the legendary Fer de Dieu, a 100-metre-long metallic mass rumoured to have been found in the Sahara desert in Mauritania in 1916, but then lost again under the shifting sands.

"Amazingly, NASA estimates that about 44 tonnes of meteorite material hits our planet each day"

The second part of the book takes us deep into what we can learn from meteorites, whether they are freshly fallen, have been trapped in ice for hundreds of years, or fell millions of years ago only to be unearthed alongside fossils.

It is a very readable outline of where meteorites originate and what they tell us about, say, the history of our solar system or the origins of water on Earth. This is fascinating stuff, if less thrilling than the pace and adventure of the the book's first half. It is in its tales of discovery that *The Meteorite Hunters* comes to life, and it may well change what you think when you look up and see a streak of light as a meteor flashes across the sky, or a meteorite lands on your doorstep. It might even have you getting out there and hunting them yourself. ▮

Chris Simms is a writer based in Somerset, UK

Origin story, part one

A driven teenager up nights working on computer schemes. Could this be Bill Gates? **Chris Stokel-Walker** explores

Book

Source Code
Bill Gates
Allen Lane

THERE are few people in the world of technology with more interesting stories to tell than Bill Gates. The entrepreneur and co-founder of Microsoft has seen computers morph from hulking machines that fill entire rooms – and cost thousands of dollars a day to use – to tiny, handheld devices that can be picked up for comparative pennies. He has seen, and changed his mind on the importance of, the rise of the internet and artificial intelligence, with his personal volte-faces shaping industry adoption. That's before you get to his work leading Microsoft – now the world's second-highest valued company at $3 trillion.

Which is why his autobiography, *Source Code: My beginnings* – which covers his early years in Seattle, Washington, up to the point he starts Microsoft with Paul Allen – has been so hotly anticipated.

Bill Gates (right) and Paul Allen, his childhood friend and Microsoft co-founder in the late 1960s

Getting into the head of someone with such a standing as Gates could produce insights into so-called tech bros more widely, and therefore the influence they have on our society.

We get plenty of self-reflection from Gates, who has always seemed somewhat more earnest, though no less sharp-elbowed, than the generation of tech entrepreneurs who followed him, which includes Elon Musk and Mark Zuckerberg. We understand more about his mercurial mind and the drive that led him to make Microsoft and usher in modern computing – and how that one-track focus stems from harnessing a bloodymindedness that infuriated teachers and rubbed his family up the wrong way.

We also understand a little more about why Microsoft is more boring (comparatively) than its peers, by being given a peek into Gates's psyche. Early vignettes highlight how caution was impressed on him, when, for instance, Gates loses badly at cards to his hustler-like grandmother, Gami, before finally besting her – only to then overstate his expertise and come a cropper at college poker games.

And we get some disarming honesty from the multi-billionaire. He recognises that as the privately educated and already rich son of a well-respected lawyer father and highly connected community-organiser mother, he had privileges that helped him on his way.

The book is eminently readable. It is deeply researched and richly told, thanks to strong family archives that have kept drunken letters to friends and loving missives from parents and grandparents. Gates's prose is well-constructed, too, even if the narrative can be repetitious (there are only so many times we can learn that as a teenager he snuck into school or university computer labs at night, watching the hours fly by in a frenzy as he coded his latest harebrained, would-be commercial project).

But the story comes to an end just as it gets really interesting. This is understandable – Gates is clear that this is the first of a trilogy – but it does leave the reader frustrated that as soon as Microsoft is set up and on the cusp of defining home computing, the book wraps up abruptly with a sidebar about a melancholy family trip to Hood Canal in Washington state. The idea seems to be to finish on a particular moment to set up the sequel, but in the end all it does is underwhelm and feel tacked on to what had been, until then, a deeply methodical walk through Gates's life.

If you are planning to read all three books to learn more about the origin story of the Microsoft billionaire, then by all means pick up *Source Code*. But if you just want to learn about how we got to the stage where almost every person on the planet has a phone in their pocket and a laptop on their desk, I would skip this one and wait for the sequels, where there will be fewer scenes from prep school and more from Microsoft itself. ▮

LAKESIDE SCHOOL

Chris Stokel-Walker is a writer based in Newcastle upon Tyne, UK

New Scientist *recommends*

Tim Boddy
Picture editor
London

To beat the winter blues, I have treated myself to two excellent pieces of escapism. **Lost Gardens of London**, open until 2 March at the Garden Museum, proved a thoroughly engaging

exhibition full of great London morsels. Who knew that the city's Southwark borough once had its own zoo?

I also enjoyed **The Employees** (pictured) at London's Southbank Centre last month, directed by Łukasz Twarkowski. This mesmerising piece of theatre is based on a book by Olga Ravn. It invited audiences to think big – what does it mean to be human, do machines feel – as they wandered about, peering into a giant neon cube, the spaceship where the action took place.

There, humans and humanoids developed relationships under the menacing eye of the mysterious Organisation. The production was outrageously ambitious technically and offered an immersive visual and sonic feast. Think TV's *Severance* (in space) meets Spike Jonze's *Her*.

NATALIA KABANOW

The sci-fi column

A kind of contact

Would humans recognise intelligence in aliens – and would the aliens recognise it back? Two women marooned on a moon try to find out in *Shroud*, Adrian Tchaikovsky's intriguing new novel, finds **Emily H. Wilson**

Emily H. Wilson is a former editor of *New Scientist* and the author of the *Sumerians* trilogy, set in ancient Mesopotamia. The second book in the series, *Gilgamesh*, is out now. You can find her at emilyhwilson.com, or follow her on X @emilyhwilson and Instagram @emilyhwilson1

SHUTTERSTOCK/IURII

What might be lurking on the surface of the unusual moon Shroud?

Book
Shroud
Adrian Tchaikovsky
Tor

Emily also recommends...

Book
The Murderbot Diaries
Martha Wells
Tor Books
It's fair to say that Shroud *(see main review) is an ideas-based novel. The Murderbot books are firmly character based, and the character in question is, of course, the delightful Murderbot. These smash hits have been republished in omnibus form in time for the release of the Apple TV+ version of the stories, starring Alexander Skarsgård as Murderbot. So if you haven't read them, now is the time. You will find they slip down very easily indeed: Murderbot is a wonderful creation.*

THE latest novel by Adrian Tchaikovsky, *Shroud*, examines the question of whether, faced with an alien intelligence, we would actually perceive it as intelligent. That and whether the aliens would recognise us as anything above pond life.

The setting is the far future and a foray by a commercial vessel into a new star system. The ship's culture is cruel, petty and highly corporate – that is, entirely recognisable to humans alive today. The crew are unfrozen, used as needed, then summarily refrozen. Everyone has an awful manager and a long job title. Our main character, Juna Ceelander (special projects, adminstrator), is a personal assistant to a middle manager, her main role being to oil the wheels between the ship's competing departments.

The crew discover a high-gravity, zero-oxygen, pitch-black moon that is alive with frenetic radio activity. They name it Shroud. The moon appears to be ripe for commercial exploitation, but it proves hard to study from a distance. All the same, no one wants to go to the surface (if it even has one) to study it up close. After all, what might be lurking down there in the very noisy dark?

A devastating accident on board results in Juna and her colleague Mai Ste Etienne (special projects, macro engineer) obliged to answer that question themselves. Marooned on Shroud in a tiny exploration pod, the two women turn on their pod's lamps and peer out... and Shroud peers right back.

> **"The ship's culture is cruel, petty and highly corporate – that is, entirely recognisable to humans alive today"**

With no way of communicating with their spaceship, and no understanding of the creatures surrounding them, our heroes decide that their only chance of survival is to make a huge voyage across Shroud to the one place from which they think they might be able to send an SOS. Cue a long, awkward, very slow, sometimes horrifying, but also sometimes very funny road trip (minus the road) across an alien world.

There is a lovely scene where our heroes, trapped in their pod, try to run through the Fibonacci sequence with the aliens, hoping for meaningful communication. They blast out the sequence up to 13. The alien creatures (or perhaps creature) merely parrot it back. The humans wait to see if the alien(s) will come up with the next in the sequence, but get nothing back. They conclude the creatures don't have maths and therefore cannot be intelligent.

The alien(s), meanwhile, decide the creature they are dealing with is simple-minded indeed. Why does it keep shouting numbers? What is its problem? When the humans stop at 13 blasts, the alien(s) concludes that perhaps the Stranger doesn't know of the existence of any higher numbers.

In the end, the two sides are reduced to communicating by issuing three blasts in a row, to be replied to with three blasts in a row: "Still here, still hearing you," but nothing more. Fortunately, this isn't the first time Juna has had to deal with extremely difficult colleagues...

This novel makes an interesting companion piece to Tchaikovsky's *Alien Clay*, published last year. That very different novel also examined alien intelligence and how it might interact with humans with potentially devastating consequences. As I wrote in my review, Tchaikovsky is writing at the very peak of his powers and he is fizzing with more interesting ideas than any one human has a right to. I look forward to whatever he does next.

Editor's pick

The problems with talk of a 1.5°C climate 'goal'

18 January, p 8

From Michael Grubb, professor of energy and climate change, University College London, UK

Anyone can look up the Paris Agreement (PA) text on curbing global warming to see that calling 1.5°C a "goal" is wrong. This matters for several reasons.

First, many lower-income countries regarded 1.5°C as fundamentally inequitable, given the implication that high-income countries had used up most of the carbon budget for this and were implicitly now trying to "cut the ladder" on the use of fossil fuels for basic industrialisation. Some thus regard the popular "1.5°C limit" narrative as a breach of trust on what was actually agreed.

Second, the limit narrative diverts from the reality that – as your leader said – there isn't a warming cliff edge, but rather that every tenth of a degree matters. The actual aim of the PA to remain "well below 2°C", while "pursuing efforts" for 1.5°C, reflects the balance of concerns.

A durable legal agreement couldn't rest on a single threshold that many considered undeliverable. Focus on 1.5°C as "the limit" risks undermining the PA's credibility.

Pandemic was perfect setting for conspiracies

4 January, p 7

From Alistair Coleman, Osmington, Dorset, UK

Your look at the lessons learned from the covid-19 pandemic largely missed one crucial aspect – that lockdown was a perfect Petri dish for conspiracy theories and blatant untruths to spread and take root across online platforms, contributing to real-world harms.

That lesson hasn't been learned; media literacy was neglected despite it being an issue long before the pandemic. Long-running mistrust in "experts" plus millions of bored people with instant access to the entire sum of human knowledge (good and bad) led to conspiratorial thought spreading from covid-19 and vaccines to just about anything in the human sphere. I doubt if we can ever roll this back.

From Beth Morrell, Raleigh, North Carolina, US

One thing about the passing of time during the pandemic wasn't that the year of lockdown seemed longer or shorter than normal, but everything from before covid-19 felt like decades ago, even by 2022.

On the discovery of a new species of marine reptile

25 January, p 21

From Nicholas Longrich, University of Bath, UK, and colleagues

You covered a study that suggests *Xenodens calminechari*, a new species of mosasaurid named by us, could be based on a forged jaw fossil. We can confirm the authenticity of the fossil.

Our team includes world experts in Moroccan mosasaurs. Having published 20 papers, described 10 new mosasaurids, examined thousands of specimens over two decades, carried out fieldwork and worked under two international official academic agreements between Morocco, France and the UK, we are familiar with recognising fossil alteration.

We can confirm the fossil's authenticity because the first author prepared the specimen from the original matrix using a pin vice and paintbrush. Any alteration would have been obvious. Furthermore, during preparation, a tooth detached, exposing the interior of the crown and root, showing both are original. The "gummy" texture identified in the study you covered as possible reconstructed material is standard Paraloid B-72 resin used to prepare the fossil for study. Last, two new *Xenodens*, identical to the holotype, are now under study. We plan further research, including CT scans, and are confident this will vindicate *X. calminechari* and lay all doubts to rest.

New wearables aren't for everyone

18 January, p 36

From Deborah Williams, Staines, Surrey, UK

Wearables meant to boost mental health sound like a nightmare. With these, I wouldn't be allowed to drift off to sleep thinking about what I want to think about – I plan the next day: where am I going for my walk, what am I having for dinner, etc. But that would bring a storm rumbling in my ears!

Threats to Antarctic wildlife are numerous

11 January, p 36

From Pamela Manfield, The Narth, Monmouthshire, UK

Your article on scientific advances helping to increase knowledge of emperor penguins in Antarctica was fascinating. However, there are other problems apart from climate change affecting these and other creatures there. Increased tourism is leading to disturbance of the penguins, especially when newborn chicks are about. Litter is an increasing problem, as is waste from ships. Even on some bases, waste-water disposal is an issue. Non-native grasses have come in on people's boots and there may be other problems not yet identified.

Like the rest of the world, Antarctica is suffering from problems caused by people.

Time is ripe to begin polar geoengineering trials

18 January, p 32

From Chris Dinsdale, Barrie, Ontario, Canada

As the world continues to react at a snail's pace to the threat of climate change, we need to at least start to experiment with geoengineering. The poles are nearing a runaway feedback loop that will forever change the Arctic and, in turn, world weather patterns. Does anyone truly believe our current governments can cut emissions enough to stop this disaster?

No one wants geoengineering as a permanent solution, but it should at least be considered as a stopgap measure. This world needs our poles to stay frozen.

From Dave Holtum, Bathampton, Somerset, UK

You indicate that we can expect more extreme weather with a wavier northern polar jet stream. I suspect this is even more likely when you consider the effects of an apparently weakening Gulf Stream and its interaction with the jet stream.

One possible effect of a disrupted Gulf Stream is a cooling of Europe. Maybe this will cancel out predicted warming. I suspect, though, that the outcome could be more extremes of cold and heat.

Your heading left me feeling pretty vacant

18 January, p 11

From Anthony Tasgal, London, UK

I was fascinated by your piece on molluscs with distinctive "punk"-like hairstyles, but think you missed a trick by not headlining it: "Never mind the molluscs". ▮

For the record

▮ **The pigeons in Aperture (25 January, p 26), clockwise from far left, are a Franconian Trumpeter, Danish Suabian, Old Dutch Capuchine, Gimpel (or Archangel) and Jacobin.**

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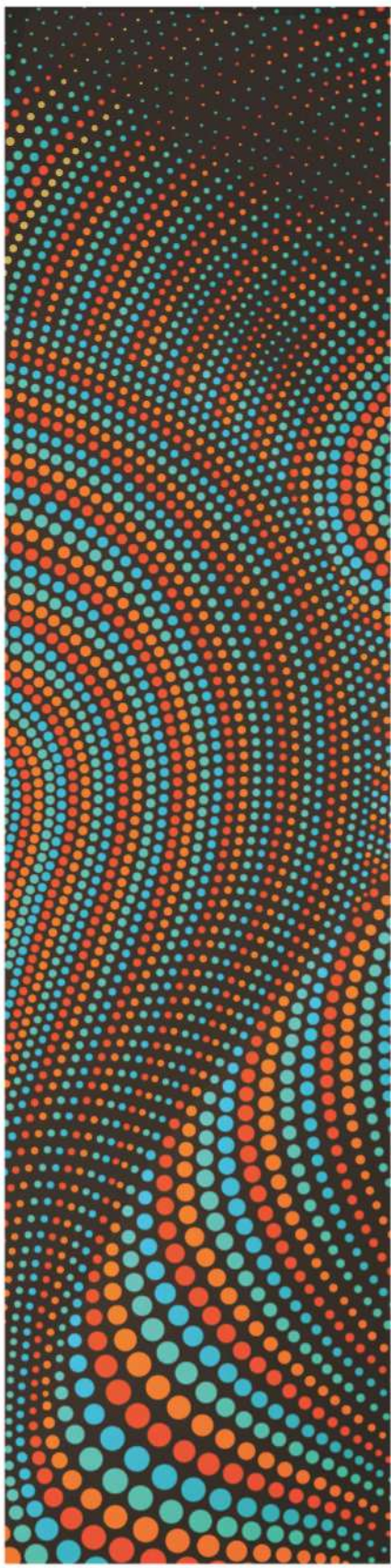
The enemy within

A new understanding of our relationship with our gut microbes shows they might not be our friends after all, discovers **Graham Lawton**



YEHRIN TONG

AS HUMAN beings, we are all keepers of a vast menagerie. Every surface of our bodies, inside and out, is teeming with microorganisms. We have microbiomes on our skin, in our mouths and other orifices and – especially – in our intestines.

In recent years, we have grown accustomed to thinking of these internal residents as benign, even essential to our health. Our guts are said to be full of "friendly" bacteria and other microorganisms that do us favours in return for us giving them a cosy home. That is true to some extent, but new research on the role of the gut microbiome in ageing is pointing to what would constitute a profound rethink of this relationship.

In this emerging view, our gut microbes aren't our friends, but an enemy at the gates. Far from being mutually beneficial, our relationship with them is more like a war of attrition – a war we eventually lose. However, there are ways to postpone the inevitable.

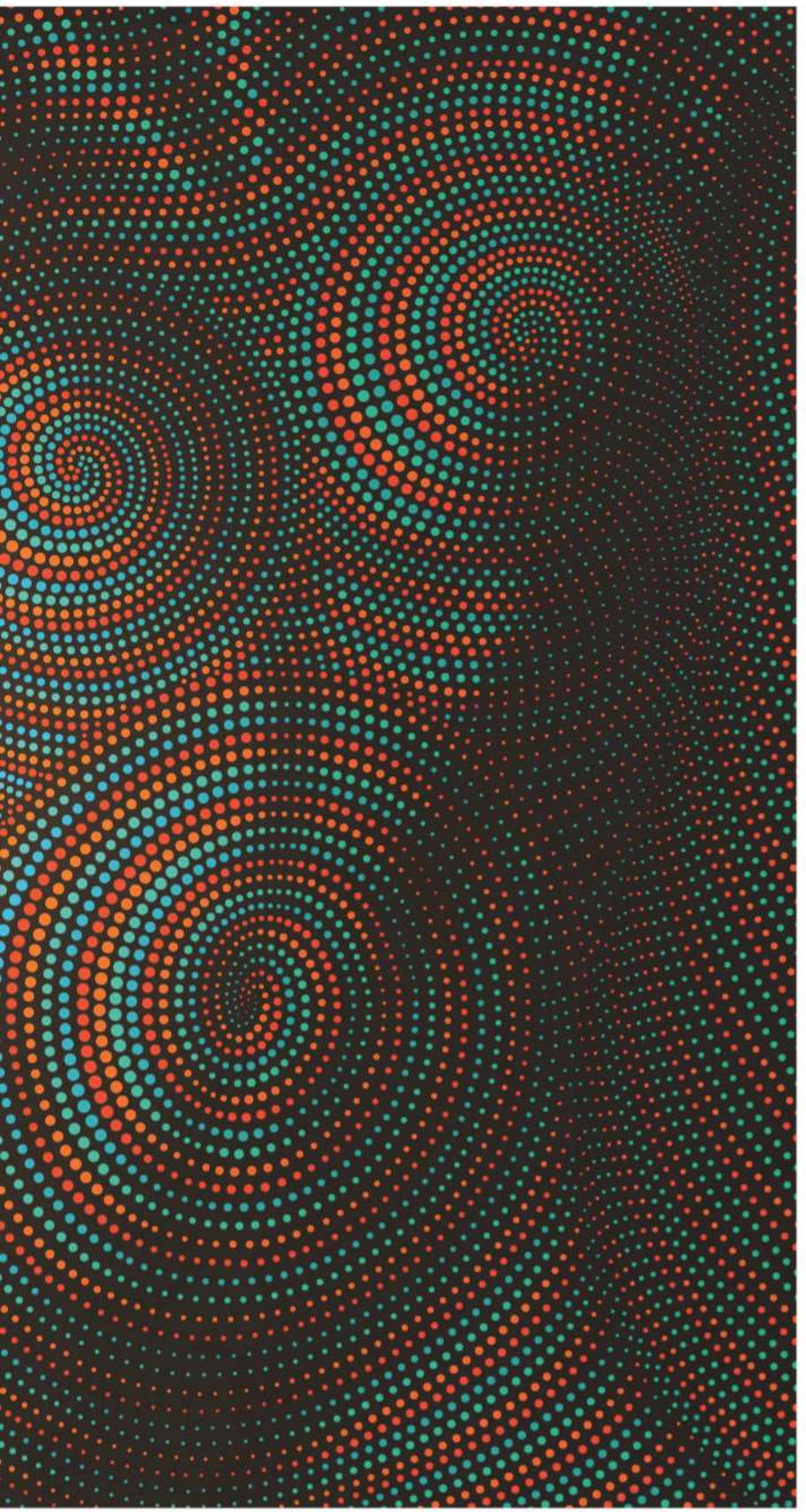
The gut microbiome is a community of perhaps 100 trillion microorganisms – bacteria, archaea, fungi and viruses – that dwell inside our intestinal tract, most abundantly in the colon. It is established early and stays with us throughout our lives, though it is in constant flux. "It's a very complex, very dynamic community that depends on what we eat, who we interact with," says Dario Valenzano at the Leibniz Institute on Aging – Fritz Lipmann Institute (FLI) in Jena, Germany.

It also changes as we age. For most of our lives, the composition of our gut microbiome stays within fairly narrow guard rails, and this arrangement works quite well for both parties. We give the microbes food, mostly in the form of dietary fibre. In return, they break down fibrous molecules that we can't digest and make the energy available to us, as well as supplying nutrients that we find hard to synthesise ourselves. They also work tirelessly to exclude less-friendly microorganisms that would otherwise colonise the gut and make us sick.

As we age, however, the relationship becomes fractious. The species composition of the microbiome changes: strains that were rare or absent begin to dominate while others dwindle or disappear. Overall, there is a loss of species diversity, and with it a narrowing of functional repertoire. This "dysbiosis" is recognised as a core feature of ageing. Until recently, however, the causes and consequences of the changes that occur weren't well understood. Now, it is being seen not just as a hallmark of ageing, but as a direct driver of it.

The idea that the gut microbiome may somehow promote ageing has a long pedigree. In 1907, immunologist Élie Metchnikoff at the Pasteur Institute in Paris, who would go on to win a Nobel prize the following year, published a book called *The Prolongation of Life*, in which he proposed that our lives many be shortened by "chronic poisoning from an abundant intestinal flora".

It was speculation, but prescient. "We actually now have a lot of evidence from many studies in many different organisms that the gut microbiome, the microbes themselves,



seem to have a key role in regulating ageing," said Filipe Cabreiro from the University of Cologne in Germany at the Aging and Microbiome conference in Jena in October.

Maria Ermolaeva, also at FLI, told the conference that for most of our adult lives, our intestinal microbiome is dominated by core species, gut specialists adapted to live inside humans. Though their exact proportions vary from person to person and over time, these species predominantly belong to three families: *Ruminococcaceae*, *Lachnospiraceae* and *Bacteroidaceae*. On the fringes, however, are subdominant species that are highly individualised and mostly acquired from the environment throughout life.

Microbial takeover

After about the age of 50, the core microbiome begins to decline and the subdominant microbiome increasingly runs the show.

The consequences of this takeover are extremely disruptive, according to Lena Best at University Hospital Schleswig-Holstein in Kiel, Germany. She told the conference that, based on recent experiments in mice, the members of the gut microbiome can be classified into three functional categories: neutral, beneficial and competitive. The first two work in harmony with each other and their host, but the third type are selfishly out for themselves.

In young adulthood, the neutrals and beneficials outnumber the bad guys, but are already on a downward trajectory, with the baddies becoming increasingly prevalent. By the time the mouse is about 30 months old – roughly equivalent to a human octogenarian – competitive species are in the majority. "The neutral or more beneficial ones are going down with age," said Best. This means that, overall, the microbes don't work together so well.

One of the most damaging effects of this shift is a loss of what is known as barrier function, according to Maria Vehreschild at Frankfurt University Hospital in Germany. In a young and healthy gut, the microbes are strictly confined within the lumen – the inside of the intestine – by the gut wall and its thick coating of mucus. But as dysbiosis progresses, competitive microorganisms increasingly breach the barrier, squeezing into the spaces between our cells and eventually entering the bloodstream. This prompts the immune system into action, resulting in low-level ›

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inflammation spreading throughout the body. This "inflammaging" is another hallmark of ageing.

"We know that microbial composition and function changes significantly with ageing," Aimée Parker at the Quadram Institute in Norwich, UK, told the ageing research conference. "Concomitant with this, we also see the development of inflammaging, this chronic, low-level, systemic inflammation which contributes to the decline of tissues and organs around the body." This has led to the question of whether dysbiosis is a cause, consequence or simple correlate of inflammaging, she said.

Profound changes

According to Selina Stahl at Ulm University in Germany, this is a classic chicken-and-egg question. "Upon ageing, we do know that both systems undergo profound changes," she told the other researchers at the conference – but which comes first? "Much work has been focusing on what dysbiosis does to immune system function," she said. "Less is really known [about] what intrinsic ageing of the immune system does to the microbiome."

To find out, she and her colleagues took haematopoietic stem cells – which give rise to most major immune cells and which, as they age, cause immune function to decline – from young and old mice and swapped them over. The mice had been irradiated to destroy their immune systems, but the transplanted stem cells grew to fill the vacancy. Once the transplanted immune systems had matured, Stahl and her colleagues analysed the recipients' gut microbiomes via faecal and intestinal cell samples. She found that young mice given an old immune system developed a microbiome typical of older mice, and vice versa. This suggests that ageing of the immune system, or immunosenescence, precedes changes in gut microbial composition, said Stahl.

The implication is that the immune system keeps a lid on the microbiome, but when that lid is lifted, the microbiome is ready and willing to storm the citadel. "This is a big question, but I think there's something inherent that breaks down first at the host level," says Cabreiro. "You remove this control over the microbiome and therefore you start having this dysbiotic microenvironment, which then fuels the entire cycle."

Further evidence that the microbiome turns against us as we age comes from a recent set of experiments in Cabreiro's lab involving an animal model called the progeroid mouse. This is a strain of laboratory mouse with a mutation in a gene called *POLG*, which codes for a protein involved in the repair of mitochondrial DNA, the genome of the energy-producing structures within cells. The mutation results in extensive mitochondrial dysfunction, which causes mice to age rapidly in a similar way to children with the premature-ageing syndrome progeria (although this condition is caused by a different mutation).

"This mouse shows very clear signs of ageing," Cabreiro said at the conference, replicating the normal ageing process and living a shorter life. Lab mice naturally live for up to 36 months or more but the progeroid mice are mostly dead within five. During their short lives, the mutant mice rapidly lose weight, muscle mass and fur, classic signs of ageing in a mouse. They also develop immunosenescence and profound inflammation in the colon.

To investigate the role of the microbiome in this process, Cabreiro's team generated microbe-free mutant mice that completely lack a microbiome. Despite the mutation still being present, these mice lived significantly longer than "colonised" mutant mice and also showed much fewer signs of premature ageing, including in their guts. They still died young, but their maximum lifespan was extended by 26 per cent.

No great surprise there, says Cabreiro. It has been known since the 1970s that microbe-free mice live longer and healthier lives than mice with a flourishing microbiome – although they do show altered metabolism, immune function and brain development. They are also more resistant to age-related diseases, including cancer and type 2 diabetes.

This was largely explained by the fact that microbe-free mice don't encounter pathogens. But that can't be the whole story, says Cabreiro, because lab mice with a normal microbiome that are sheltered from pathogens are also shorter-lived and less healthy than their microbe-free counterparts. There must be something about having a microbiome that reduces health and longevity.

Discovering exactly what is still very much a work in progress, but there are hints. Cabreiro has found that the energy required to maintain a microbiome exerts a great toll on the host's metabolism, which could contribute to immunosenescence and general ageing.

"Gut microbes seem to play a key role in regulating ageing"

STOCKFOOD/GONTAR, YULIYA

This led him to what he calls a provocative idea: maintaining the microbiome is actually a huge burden that ultimately reduces our lifespans and, in an ideal world, we wouldn't need one at all. "I'm not entirely sure anymore whether there's any good microbe," he told the ageing research conference. "We constantly talk about good and bad microbes. From a purely ageing perspective, so far all the evidence that I've seen is that germ-free animals are actually healthier and better than any colonised animal. Yes, of course, in the real world, we do need a microbiome, but it does carry a cost."

But what about all the vital services that our friendly bacteria provide? Again, the fact that microbe-free mice thrive suggests that these microbes aren't vital at all. Yes, a healthy microbiome provides metabolic services and has important functions, but these aren't a matter of life or death it seems.

In reality, of course, living without a microbiome isn't an option. We are surrounded by microorganisms that inevitably colonise us, many of which are dangerous. "If we were living in a condition where we're not challenged every day, we

RICHARD KALVAR/MAGNUM PHOTOS

A high-fibre diet and spending time with younger people can rejuvenate an ageing gut microbiome

didn't have viruses and pathogens trying to kill us, then we would be much better off not having this association," says Cabreiro. "It's almost a marriage of convenience."

Strained relations

This is all in keeping with recent research on how hard our immune systems have to work to keep our gut microbiomes on a leash – a process called host control. "There are two components to it," says Jacob Wilde at the University of Oxford. "Innate immunity, which includes the mucosal barrier to contain microbes and prevent them from being where they're not supposed to be, [and] there's also adaptive immunity." The latter takes the form of antibodies secreted into the gut to eliminate microbes that threaten to worsen those strained marital relations. "The innate system is probably the part that requires the most resources, or has the most cost for the host," says Wilde. "I'm not sure how much mucus is secreted in total, but it must be an awful lot, at significant cost."

He, too, has come to the conclusion that the gut microbiome has been given too much of an easy ride. "There's this thought that our microbes have our best intentions at heart and they're inherently good. But I think that heavily misses the mark," says Wilde. To see their true intentions, consider what happens when control by the host is permanently lifted, he says. "When we die, our microbes eat us. Within 30 minutes or something, you've got microbes in your bloodstream and then they go to most of your organs and you swell from inside as they start to break down your tissues."

Is there any way of postponing that gruesome outcome by exerting host control for longer? "We know that exercise has a really beneficial effect on your immune system," says Parker, "and because of the interaction between your immune system and your microbiota, that's the best thing you can do to keep everything working well."

Many other lifestyle factors worsen dysbiosis, says Vehreschild. A course of oral antibiotics can radically and persistently alter the composition of the gut microbiome. The culling of certain classes of bacteria breaks what is known as colonisation resistance – the collective efforts of the microbiome to exclude outsiders – allowing undesirable species to gain a foothold.

Many other therapeutic drugs also weaken colonisation resistance, including anti-inflammatories, antidepressants, diabetes drugs and proton pump inhibitors for controlling stomach acid. A landmark paper in 2018 found that 1 in 300 non-antibiotic drugs have this effect.

Poor diets are another source of trouble. Many gut bacteria derive energy from dietary fibre, but will switch to consuming the mucus lining the intestine if they are being starved. Low-fibre diets can also tilt the balance away from these bacteria and towards mucus-eating specialists. This gradually breaks down the mucus lining and leaves the gut wall vulnerable to breaches. "When you take all these little things together, you have a lot of components that look similar to what happens when you look at immunosenescence," says Vehreschild.

You can also reinvigorate your microbiome by spending time with younger people, because we pick up a lot of our microbes from those around us, says Valenzano.

In the longer term, faecal microbial transplants – where young microbiomes are transferred to older people – look encouraging, at least in animal models, says Vehreschild. She is currently trying to set up a clinical trial to test whether these transplants reduce biomarkers of ageing in older people. This is a promising approach, says Parker. "We find consistently that if you transfer young faecal microbiomes into an older recipient, then you reduce some of these markers like inflammation and other indicators of ageing."

Ultimately, though, if you live long enough, your gut microbiome will eat you alive. Thankfully, that doesn't negate the things that many of us already do to cultivate a healthy one. But we need to stop thinking of our gut bugs as our friends and start seeing them for what they really are: frenemies. "I think it's important for the field to move beyond saying that the microbiome is the solution for everything," says Cabreiro. "It's conceptually simplistic, and very likely wrong." ▮

Graham Lawton is a staff writer at *New Scientist*

Destination: Phobos

The origin of Mars's bizarre moon is still a mystery, but an imminent mission is set to finally provide answers, reports **Nadia Drake**

NEXT to Earth, Mars may be the most-studied world in our solar system, currently home to a fleet of orbiters, landers and rovers. But above the red sands on which the rovers trundle, a strange moon rises twice each day. And despite all the scrutiny that Mars itself receives, this moon, Phobos, remains shrouded in mystery.

Phobos and its smaller neighbouring moon, Deimos – both discovered in 1877 – are two of the most perplexing worlds in the solar system. "They're the only objects at this stage, in the solar system, for which we have pretty much no idea what they are," says Pascal Lee at the SETI Institute in California. "We know what other moons are. We know asteroids and comets. Phobos and Deimos? No idea."

The Martian moons might be captured asteroids, or they could have formed from the same disc of primordial planet-stuff as Mars. Perhaps they were forged from a fiery cataclysm like the collision that crafted Earth's moon. Or maybe their origin story is something else entirely. "What the heck are they?" asks Abigail Fraeman at NASA's Jet Propulsion Laboratory in California. "I think this is one of the great mysteries of planetary science."

Now, there is hope we might finally solve that puzzle, thanks to a new mission to Phobos that is in the works. Doing so would offer more than just a satisfying answer: it could also open a new window on the history of the inner solar system, and perhaps point to the source of life's building blocks on Earth.

It is fair to say that figuring out the origins of Mars's moons – or indeed learning anything conclusive about them – hasn't been much of a priority. So far, most of what we know about the pair comes from Mars-focused missions that happened to spare some time to observe the rusted world's little moons. "Phobos and Deimos have always been these sort of neglected worlds because they're attached to such an interesting world – Mars," says David Minton at Purdue University in Indiana. "They've always been afterthoughts."

By the 1950s, astronomers had calculated that Phobos circles Mars every 7.5 hours and that Deimos, the outer moon, completes an orbit every 30 hours. They had also figured out roughly how big the moons are – which is to say, tiny. Phobos, the larger of the two, is just 27 kilometres across at its widest point.

More oddly, Phobos is spiralling inwards, falling towards Mars at a rate of nearly 2 centimetres per year. For the dynamics of that descent to work out, astronomers calculated that the moon's density must be astonishingly low, a conjecture that has been tough to explain by nature alone.

So strange is Phobos that one Soviet scientist even seriously wondered if it might be of alien construction. "Could Phobos be indeed rigid on the outside – but hollow on the inside? A natural satellite cannot be a hollow object," astrophysicist Iosif Shklovskii wrote in *Intelligent Life in the Universe*, the 1966 book he co-authored with astronomer Carl Sagan (who, perhaps not-coincidentally, drove an orange Porsche with the licence plate "PHOBOS"). "The idea that the moons of Mars are artificial satellites may seem fantastic, at first glance," he wrote. "In my opinion, however, it merits serious consideration." ›

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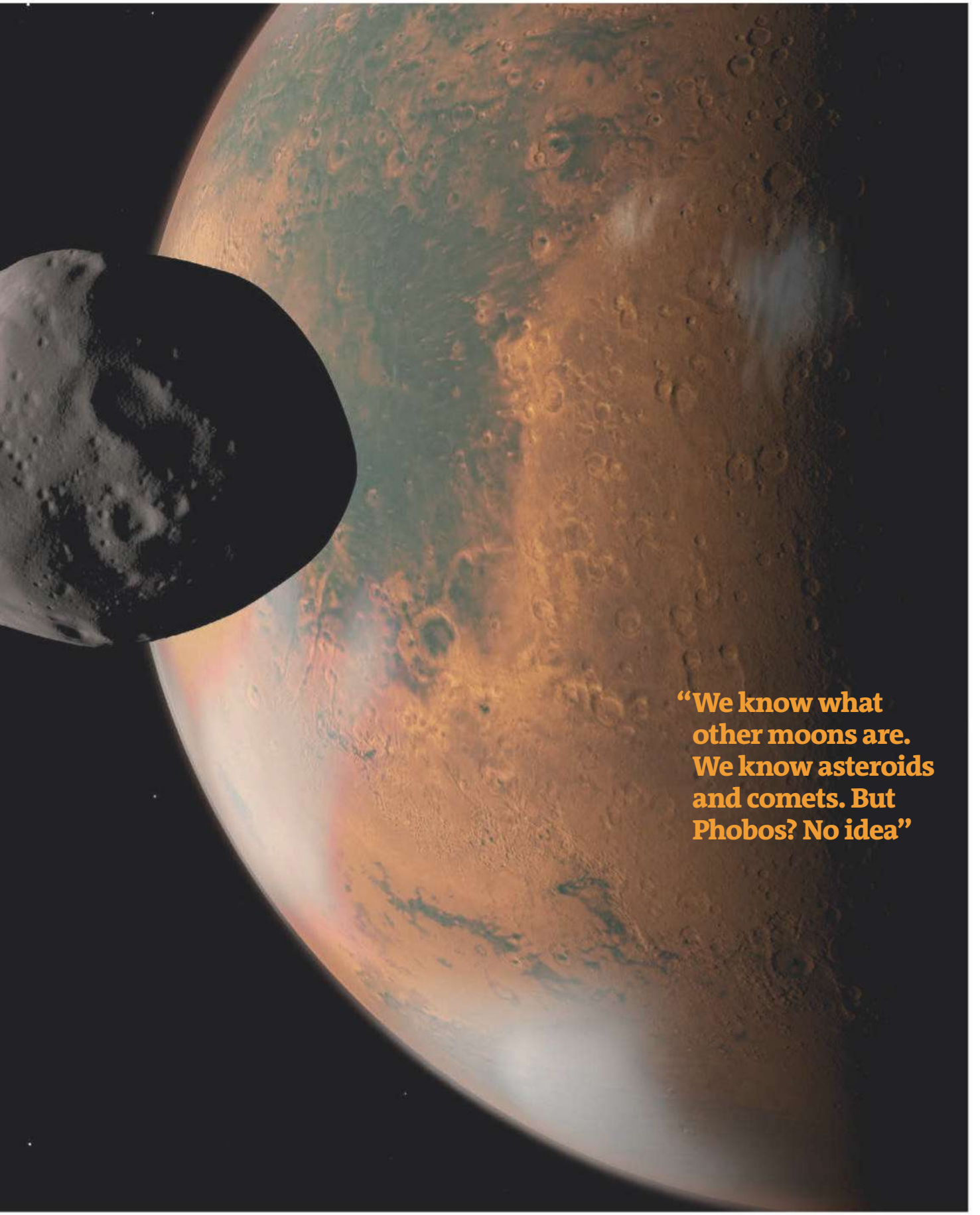


“We know what other moons are. We know asteroids and comets. But Phobos? No idea”

Revealing the origin of Phobos
Learn about the 2026 mission to Mars's bizarre moon at **newscientist.com/video**

Today, we know with certainty that Phobos isn't an alien space station. Astronomers have discovered that many asteroids are what are known as "rubble piles": loose agglomerations of debris that contain multiple internal cavities. The measured density of Phobos is consistent with a rubble pile, too. But it is still true that the moon is falling towards Mars and that, within the next 100 million years, it will either smash into the planet or be ripped apart to form a ring that will rain down on Mars over millennia. "Phobos is kind of a quirk," says Minton. "If it's 4.5 billion years old, like everything else in the solar system, we just happen to be watching it during the last tiny percentage of its life."

From decades of observation, we have learned little more than the following: Phobos is deeply weird (as is Deimos). It rises in the west and sets in the east, twice each Martian day. It is much darker than the peachy Martian surface – in fact, it is one of the least reflective bodies in the solar system. Unusual, unexplained grooves disrupt its pockmarked surface, along with a gargantuan crater named Stickney.

Impossible moons

Not only do Phobos and Deimos look nothing like Mars, but their surface composition is different too. We have found as much from spectral analysis, where astronomers study the precise wavelengths of light the moons absorb to get a handle of what they are made of. This has shown that the moons' surfaces closely resemble a type of dark asteroid rich in water and organic compounds that lives near the outer edge of the main asteroid belt, between the orbits of Mars and Jupiter. As a result, many scientists think the moons are captured objects, primordial bodies loosed from their natal grounds during a period of upheaval in the early solar system and snared by Martian gravity.

They could also be from even further out. A recent analysis by Sonia Fornasier at the Paris Observatory in France and her colleagues suggests that, spectroscopically, Phobos and Deimos look more like two parts of a dead comet that broke apart when it was pulled into Mars's orbit. "I'm really intrigued by the idea that they are a captured body," says Fornasier. "From where? I don't know."

The big problem is that the moons orbit Mars in exactly the wrong way for those capture stories to make sense. Their paths are tidy – nearly circular around Mars's equator – but we expect to see this alignment when moons form from the same cloud of stuff as their planet. It can also happen when they coalesce within a debris ring produced by a giant impact, perhaps the collision that carved the mammoth Borealis basin at the Martian north pole. "It's incredibly difficult to get a spacecraft to achieve that orbit when you have rockets on it, let alone a lump of rock," says Minton.

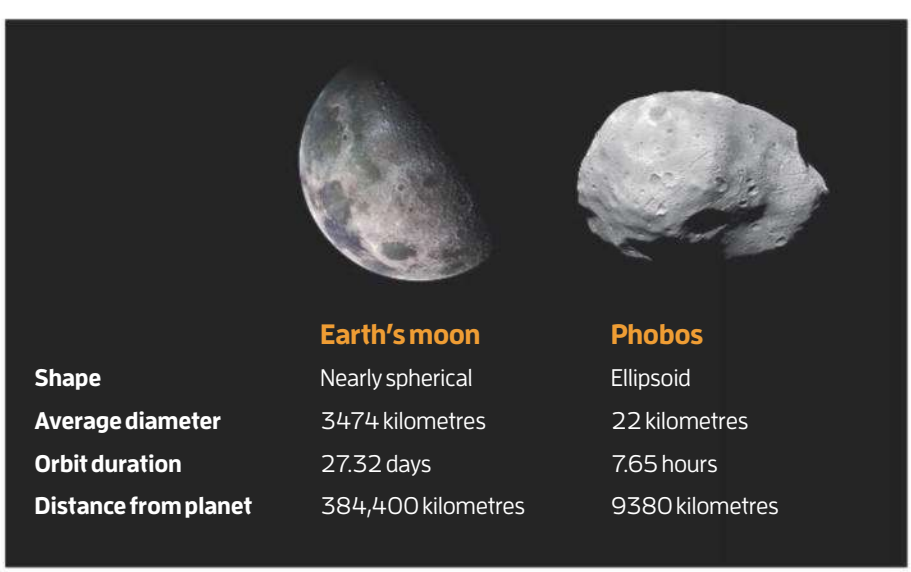
> **"On one side of Phobos, Mars would forever be in the sky; on the other, you would see endless stars"**

Captured objects, conversely, tend to trace irregular orbits: their paths are oval, tilted relative to a planet's equator and, in some cases, take them in the opposite direction to the planet's spin. In other words, it is vanishingly improbable that Mars captured both Phobos and Deimos and set them on their current routes. But if they formed at Mars, from the same ingredients as the planet, how can they look so different to the planet itself? "I think one thing one day and another thing another day," says Fraeman. "My favourite hypothesis right now is that they are from an impact, but what remains is mostly impactor that's mixed with a little bit of Mars."

One thing that would help us solve the mystery would be to actually send a dedicated mission to Phobos. But though a number of such programmes have been considered over the years, the only previous attempts – all Soviet and Russian craft – failed. The first, Phobos 1, was lost on its way to the Mars system in 1988. Phobos 2 successfully reached Mars the next year, but malfunctioned shortly after arrival. And the third, a 2011 sample-return mission called Phobos-Grunt, never escaped Earth's atmosphere. "It was a gorgeous midnight launch into a clear and frosty Kazakhstan sky," recalls Leonid Gurvits, an astronomer and expert in Russian space history at Delft University of Technology in the Netherlands. "But it was the only nice thing about that launch. The rest of the story was very sad."

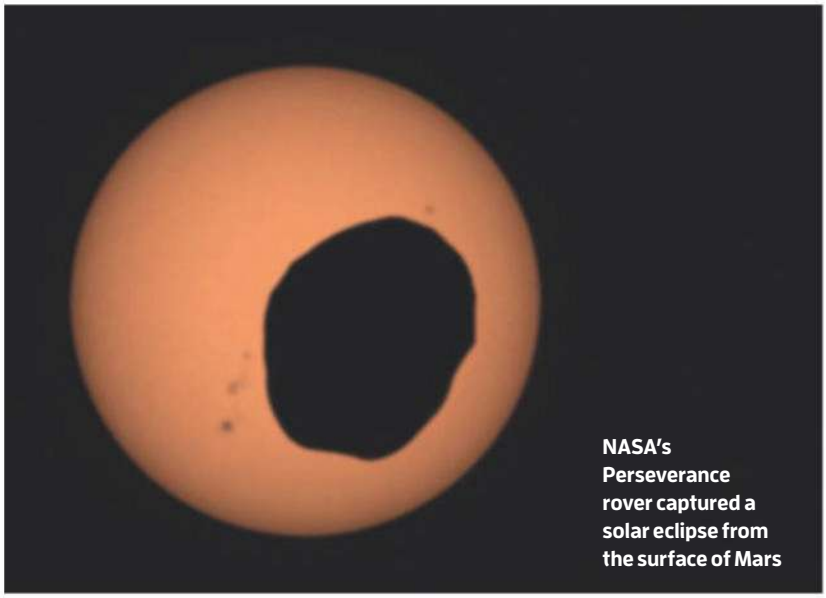
Now, it is time to try again. In 2026, the Japan Aerospace Exploration Agency (JAXA) is due to launch the Martian Moons eXploration (MMX) probe to surveil Phobos up close – and, if all goes well, to collect samples from its surface and return them to Earth.

The mission's scientific instruments will make detailed 3D maps of Phobos and the composition of its surface and collect reams of data. But the true treasure will be the trove that MMX brings back to Earth. Over just 2.5 hours, the craft will scoop up what it can before lifting off and leaving the Mars system in 2030,



	Earth's moon	Phobos
Shape	Nearly spherical	Ellipsoid
Average diameter	3474 kilometres	22 kilometres
Orbit duration	27.32 days	7.65 hours
Distance from planet	384,400 kilometres	9380 kilometres

NASA/JPL/USGS; ESA/DLR/FU BERLIN; G. NEUKUM/SCIENCE PHOTO LIBRARY



NASA's Perseverance rover captured a solar eclipse from the surface of Mars

NASA/JPL-CALTECH/ASU/MSSS/ISSI

returning to Earth in 2031. And then the real fun begins, because no instrument we have yet launched into space has the analytical power of our labs back home.

"It's the first sample-return mission from the Martian gravity field and the Martian satellite Phobos," says JAXA's Tomohiro Usui, a cosmochemist on the MMX team. The samples are expected to conclusively solve the mystery of Phobos's origins, he says, even if that means going through them grain by grain. "With laboratory experiments or real samples, you can investigate in detail the elemental composition, see if it is a captured body, maybe a comet, or if it was formed in situ," says Fornasier.

If Phobos was once an asteroid – or even a more comet-like body that was born even further from the sun – it would add to our story about how habitability evolved in the inner solar system. "That will tell us something very important about mechanisms that deliver these very important ingredients to the inner planets," says Fraeman.

For now, the origin of Earth's water and organic chemicals is somewhat mysterious. But the prevailing idea is that those vital compounds formed far from the sun, where temperatures are cold enough for them to condense on small, icy bodies such as asteroids. Then, the thinking goes, the giant planets shuffled around in the early days of the solar system and the gravitational turbulence prompted the icy bodies to pinball in all directions, including inwards on a collision course with Mars and Earth. The resulting impacts could have been responsible for bringing water and carbon-based molecules to our planet.

If, on the other hand, Phobos turns out to look like a lopped-off chunk of Mars, then we will learn something more about the history of Mars itself. We will find out what the building blocks of primordial Mars were like and which materials were floating around in the early inner solar system. That information can then be fed into simulations of how Mars evolved, says Fraeman, which will help us better understand its inner workings.

We would equally be able to use the MMX samples to figure out when the Phobos-forming impact occurred, if it indeed happened, says Usui. Depending on its precise timing – whether this took place before or after the Jupiter system coalesced – we will learn more about how giant planet formation and migration affected Mars, Earth and the rest of inner solar system. In a scenario where Mars snared Phobos from further afield, scientists could pin an age on the time of capture. That would be a harder date to work out, says Usui, but it can be done and it should tell us "whether that was because of Jupiter's turbulence, or not".

A way station to Mars

There could be an additional bonus prize to be won from a trip to Phobos, too. For all our studies of Mars, one thing we have never yet done is scoop up and return home a piece of the Red Planet. NASA's Perseverance rover has been collecting and storing samples with just this goal in mind, and the agency had planned to send a mission to bring those samples to Earth. However, the plans have been hit by delays and budget problems.

The MMX mission might offer us another chance because, regardless of Phobos's origins, it has accumulated dust from its host planet, potentially for billions of years, along with bits of Mars that have been launched into space by impacts. "It could have collected Martian meteorites throughout Martian history, or for as long as Phobos has been what it is," says Lee. "You could have samples of Mars sitting on Phobos that are better preserved than you would be able to find on Mars today." If we are really lucky, those samples could help us learn whether Mars was habitable – or even inhabited.

"We are going to get more than 10 grams of Phobos's materials... and maybe 10 milligrams of Martian samples. Ten milligrams is so huge for a cosmochemist," says Usui. "That is my kind of realistic dream. It's going to be real."

Even beyond that, MMX could be a stepping stone towards establishing a human presence in Mars orbit, perhaps with Phobos as an outpost. Despite the general focus on sending humans to Mars, there have been plenty of calls to head to Phobos instead. Being smaller, it is much easer to land on and take off from, and it would serve as a perfect place from which to operate robots on the Martian surface.

Life on Phobos would be strange. As is the case with our moon, it is tidally locked, meaning it always points the same face towards Mars. On one side of Phobos, Mars would forever be in the sky; on the other, endless stars. Its gravity is extremely weak, only about one-thousandth that of Earth's. If you jumped with enough oomph, you might rise some 350 metres and then gently descend over the course of many minutes. In any sort of structure, "you'd be forever bumping your head on the ceiling", says Lee. Even travelling in a vehicle at as little as 45 kilometres an hour would be enough to launch you from the moon entirely. "That's both the wonder and challenge of Phobos," he says.

Rather than establishing a permanent outpost on Phobos, Lee argues that it would be smarter to pull into Mars orbit, strap on a jetpack and make a short trip to the bizarre moon's surface. Just a short jaunt from Mars, Phobos could be a logical place to store Martian samples for humans to retrieve.

But those ideas will change, says Lee, if the gravity instrument on MMX reveals that Phobos is cavernous and filled with large amounts of ice – the raw material needed to manufacture rocket fuel in orbit. "That could be a game changer," he says. "If Phobos and Deimos are volatile-rich or water-rich, then all bets are off in terms of their human future." ▮

Nadia Drake is a science journalist based in the US, specialising in astronomy, planetary science and space exploration

"Women's neuroscience just isn't a field – we are so far behind"

We study male and female brains as if they are the same. **Emilė Radytė** tells Helen Thomson why that's a big mistake

THERE is a huge hole in our understanding of the brain. A gaping, woman-shaped hole. While neuroscience has given us countless insights into how our minds work, history reveals a major oversight: most of those studies were performed on both men and women without considering that there might be differences between their brains. Only recently have we begun to realise the impact of this blind spot. For example, research has now shown that the brain is dramatically remodelled after giving birth, while another study found that the fluctuations of the menstrual cycle affect how the brain works.

This oversight not only leaves us in the dark about how reproductive stages affect the brain, but calls into question many other, broader conclusions in neuroscience. It is also what inspired neuroscientist-turned-entrepreneur Emilė Radytė to co-found a start-up called Samphire Neuroscience, where she is using non-invasive brain stimulation to transform our understanding of conditions that predominantly affect women, from premenstrual syndrome and period pain to postpartum depression. *New Scientist* asked Radytė how a better understanding of women's neuroscience could change the way we treat mental health issues – and about the implications of this emerging field for everything we previously thought we knew about the human brain.

Helen Thomson: You trained as a neuroscientist. How did you come to use that expertise to develop a brain stimulation device?
Emilė Radytė: Throughout my undergraduate degree, I worked as an emergency medic. I realised that about 50 per cent of our cases were actually psychiatric emergencies. You think about paramedics helping someone who is bleeding or having a heart attack, but I was seeing addiction, suicide, rapes – the things they don't teach you how to manage. I realised there was so much unmet need in the field of psychiatry. It's the only field of medicine that is still diagnosed by a book [a psychiatry "bible" called the DSM-V] and it's so subjective, it's really shocking. I felt that mental health, and the field of psychiatry in general, was very outdated, and it was where our recent understanding of brain stimulation could really transform people's health. ›

BECKI GILL

Brain stimulation isn't new: it was on course to be the next big thing in the 2000s. Why didn't that happen, and what has changed now?
Brain stimulation has been around for about 30 years, but it was expensive, so not widely used. There was no standardisation, so researchers would deliver electric currents in whatever way they wanted. It was all a bit rogue. Then came the idea of human augmentation – trying to stimulate the brain to be a better version of yourself. But most of us already operate at 100 per cent, so improving on that was really hard.

So the protocols weren't standardised, the wrong questions were being asked and the field was abandoned to some extent. But since then, there's been a lot of work on invasive brain stimulation [which uses electrodes implanted in the brain] to understand the mechanisms of how brain stimulation works. What that meant is that when the non-invasive field was reborn, people knew that it could work, we just needed to identify the circumstances under which it works.

Brain studies generally don't account for changes in the brain due to the menstrual cycle

MIGUEL MEDINA/AFP VIA GETTY IMAGES

OLENA MALIK/GETTY IMAGES

Why did you think brain stimulation might be a good treatment for mental health conditions?
I think we've all swallowed this pill that it's normal to take a drug to manage our mental health, but the brain only gets a small percent of the dose of an entire antidepressant, the rest gets degraded and delivered to all your other organs. So, we increase the dose and then essentially poison our bodies in the process. Antidepressants are game-changing for a lot of people, but many discontinue them because of the side effects. To me, if you can stimulate the brain directly, you avoid all of the side effects to the body, and that just makes a lot more sense.

Your company has developed Nettle, a transcranial direct current stimulation device that uses low-level electrical current to modulate brain activity. It is designed with women's health in mind – tell me how that came about.
I was running interviews with people with depression, and a lot of them were women. I asked them, when did your symptoms start? And I kept hearing over and over, "my menopause started and then my depression started" or "I had my second child and suddenly it hit" or "I'm always kind of low, but in the weeks leading up to my period, I get really depressed". It struck me that their symptoms were often related to these significant reproductive shifts. What was interesting was that most women go through the same hormonal transitions every month, or after giving birth or during menopause, so why do some women's brains react in this maladaptive way and not others? I got interested in the mechanisms behind this and started looking into the literature. And I couldn't find anything.

Nothing?
We created our company in 2021. The first paper that looked at whole brain dynamics throughout the menstrual cycle was published in November 2023. There were some earlier studies that showed changes through a particular phase of the cycle, but they tended to have too few participants – it wasn't workable data in terms of conclusiveness. I didn't realise how far behind we were. Women's neuroscience just isn't a field.

With so little research out there, how did you come up with Nettle?
There were a couple of pieces of work that had recently come out of Brazil. One study tracked women with period pain and stimulated their motor cortex for five days in the week leading up to their period. They hypothesised that this would down-regulate pain perception before your period, so you experience less period pain when it happens. They showed significant effects, so that was super exciting. At the same time, another lab stimulated the prefrontal cortex in a similar way and showed improvements in PMS symptoms, especially anxiety. We looked at that data and thought, if we were to combine the two stimulations, they might work even better together, because reducing pain reduces anxiety and vice versa.

Having a baby dramatically alters a mother's brain

What did your trial show?
We ran three usability studies to make sure people could reliably use the device by themselves at home – that was really important to us. Then the two professors who ran the previously mentioned studies led a [triple-blinded, sham-controlled] trial of our device. Women who experienced PMS and period pain used Nettle for 20 minutes over the five days leading up to their period. Two-thirds of the women said their mood improved and 72 per cent of participants' pain diminished within a single month. There was a more than 50 per cent reduction in pain level. That's around the same level of reduction you need to show to get pharmaceutical painkillers approved.

A PHP-COCHIN-VOISIN/PHANIE/SCIENCE PHOTO LIBRARY

"A woman's memory changes depending on the phase of her cycle"

Can you explain the mechanisms that underpin this finding?
It has been shown that in the week leading up to your period, the two hemispheres in the prefrontal cortex become imbalanced in terms of their alpha wave activity. The left hemisphere becomes less active than it normally is and the right hemisphere becomes hyperactive. This is similar to the neural pattern seen in people with depression. As a result, the prefrontal cortex – which is responsible for managing emotions – can't communicate effectively, meaning that people can't modulate their emotions. PMS has various symptoms – low mood, anxiety, mood swings, irritability – but a lot of that comes down to mismanagement of emotion due to that alpha wave imbalance.

What we do is actually fairly simple: we stimulate the left prefrontal cortex, which is underactive, and modulate the right hemisphere to get that balance back. We also target the motor cortex. There, we see elevated theta brainwaves in people who experience painful periods. The argument is that your brain is oversensitive to pain. When we stimulate the motor cortex, we think we reduce theta waves and indirectly stimulate the posterior insula, which is a region very deep in the brain responsible for setting pain sensitivity thresholds. By stimulating it, we inhibit it, and your pain threshold increases. We're going to be doing fMRI studies to confirm these mechanisms.

Can people buy a Nettle to use at home?
Yes, it's available in the UK and Europe.

What's next for the company?
We're running a trial to test Nettle in people with endometriosis and chronic pelvic pain. That would be a game-changer because endometriosis has lots of underlying issues, but pain management seems to be the biggest problem. The other area we're looking into is premenstrual dysphoric disorder [a more severe form of PMS], to test the best protocols for that. We're also looking at using it to help with postpartum depression and anxiety.

Aside from direct impacts of reproductive biology, do you think we have missed any other important effects by not studying female brains in isolation?
The answer could be that there's no difference between the way that men's and women's brains respond to things, but we've never actually separated the data. Like, we just assume we know how memory works, but it has always been studied either on male brains or on male and female brains, not accounting for the phase of the female cycle. It now seems that memory does change depending on the phase of the cycle.

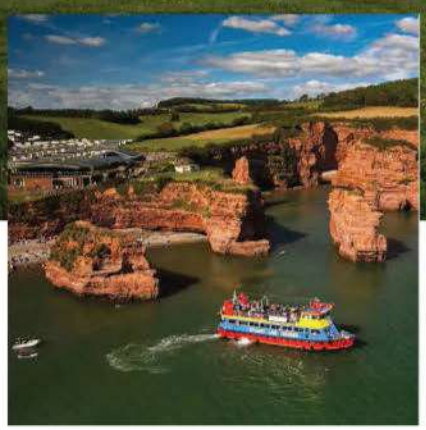
It could be that when we separate women's and men's data, we'll suddenly see huge differences. But we have 30 years of neuroscience data that we can't retroactively analyse because we never collected in the first place. Historically, we haven't used sex-segregated data in neuroscience.

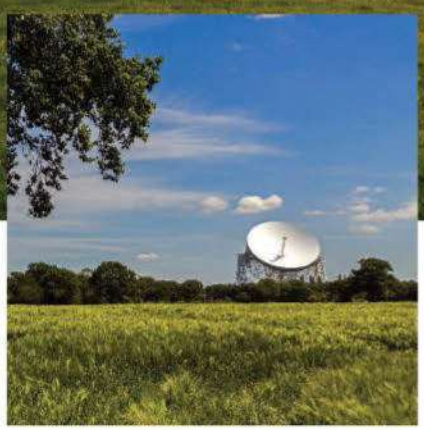
Doing that would presumably benefit our understanding of the male brain too.
Yes. It's not about women's or men's neuroscience. I'm pushing for better data – we still don't understand, for example, the impact of circadian rhythms on the brain. Men and women have a day and night cycle, but we don't normally record what time our data was taken, which we now know has massive effects. For women, we need to account not only for the circadian rhythms, but also the menstrual, menopausal and gestational cycles. Unless we do that, we're probably hiding a lot of signals or interpreting things completely wrong. ▮

Helen Thomson is a writer and author of *Unthinkable: An extraordinary journey through the world's strangest brains*

Discovery Tours
NewScientist

Short breaks in the UK





The science of the Jurassic Coast: Dorset and Devon

16 May 2025 | 3 days

Explore the science of the iconic Jurassic Coast, from its ever-changing landscapes to the future of its beaches, with insights from geologists, palaeontologists and conservationists. Here, 185 million years of Earth's history are laid out within the striking cliffs, offering an exceptional opportunity to study fossils and rock formations.

- **Enjoy insightful talks from a range of experts covering topics including human history, palaeoart, vertebrate evolutionary history and geological formations.**
- **Hunt for fossils along Lyme Regis's famed ammonite pavement accompanied by experts from the Jurassic Coast Trust.**
- **See the Jurassic Coast from a unique vantage point on a scenic cruise.**

Mysteries of the universe: Cheshire

27 June 2025 | 3 days

Spend a captivating weekend delving into the mysteries of the universe with an exciting programme that includes a special excursion to Jodrell Bank, home to the iconic Lovell Telescope. Engage with leading astronomers, astrophysicists and cosmologists as they illuminate the latest discoveries in space science, covering topics from galaxy formations to groundbreaking research on black holes.

- **Enjoy a series of fascinating lectures that will cover topics from the big bang through to the James Webb Space Telescope.**
- **See images of the southern hemisphere's skies through a remote astronomy demonstration that connects with a telescope in Australia.**
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Human origins in the prehistoric south-west

14 July 2025 | 5 days

Immerse yourself in the early human periods of the Neolithic, Bronze Age and Iron Age on a gentle walking tour exploring the prehistoric sites of Wiltshire and Dorset. From complex Iron Age hillforts and ancient stone circles to some of the area's most beautiful landscapes, discover this quaint region of south-west England.

- **Visit several prehistoric sites, including the UNESCO World Heritage sites of Stonehenge and Avebury.**
- **During this tour, you will be joined in Cerne Abbas by *New Scientist*'s former editor-in-chief Emily H. Wilson, who will lead a guided walk around this prehistoric landscape.**
- **Visits to National Trust, English Heritage and UNESCO-listed sites, including Old Sarum and Maiden Castle, with a special behind-the-scenes tour of the Wiltshire and Salisbury Museums.**

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newscientist.com/tours

Mathematics of life

Cracking the code

Barcodes contain a checksum – an ingenious use of mathematics that even lends itself to a party trick, says **Katie Steckles**

Katie Steckles is a mathematician, lecturer, YouTuber and author based in Manchester, UK. She is also adviser for *New Scientist*'s puzzle column, BrainTwister. Follow her @stecks

SOMETIMES there are hidden patterns in numbers you might not immediately notice. One example of this is in barcodes, the sequences of digits we use to identify products.

Try it yourself – find an object with a 13-digit barcode. (If you are in the US, a 12-digit barcode will also work, if you imagine an extra 0 on the front of it.) Books won't work, since they use a slightly different system, but magazines do, so you can use a copy of *New Scientist*. Add together the first, third, and fifth digits and so on, to get the sum of the odd-numbered digits; then, add up the even digits. If you triple the even sum, and then add it to the original odd sum, the total should be a multiple of 10, ending in 0.

This isn't a coincidence: a barcode contains a checksum, ensuring that when it is scanned, it has been read in correctly. Most of the digits are there to communicate information. The first two are a country code (50 means it is a product produced in the UK). The next 10 digits are more specific information about the product and who produced it.

The purpose of the final digit is to detect errors or changes in the data, such as swapping two digits, or entering one incorrectly. This would give a checksum that isn't a multiple of 10, allowing us to catch the error.

Barcode scanners use lasers to pick up the pattern of stripes, which encodes the same numbers. But these scanners are often cheap and can make errors, especially if the barcode is on a curved or shiny surface. So if you scan a barcode in a supermarket, it will read in the digits, compute the checksum and only beep if it is right – and until it gets a correct read, it won't accept it.

SHUTTERSTOCK/SCOTT ROTHSTEIN

All kinds of systems have checksums: ISBNs on books, which use a similar system based on multiples of 11; UK driver's license numbers, which have two extra check digits at the end; and credit card numbers, meaning a website can tell you have entered it incorrectly before even checking with your bank. They all use variations of the same system, performing a simple calculation with the digits that confirms the number is valid.

It won't eliminate errors – for barcodes, there is still a 1 in 10 chance the checksum will come out as a multiple of 10 even if there is an error – but it greatly reduces them. It also doesn't tell you what the error is, so all you can do is try scanning the number again. But it saves time that would otherwise be wasted trying to process incorrect numbers, and it is an ingenious use of maths that makes the whole system more robust.

And if you were looking for a practical application, here is a great party trick: ask someone holding a bottle to read out all but one digit of the barcode, and with a bit of practice you can tell them the missing number. Maybe you'll even earn yourself a free drink! ▮

Mathematics of life appears monthly

Next week
Debunking gardening myths

These articles are posted each week at newscientist.com/maker

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Company Wayne McGregor

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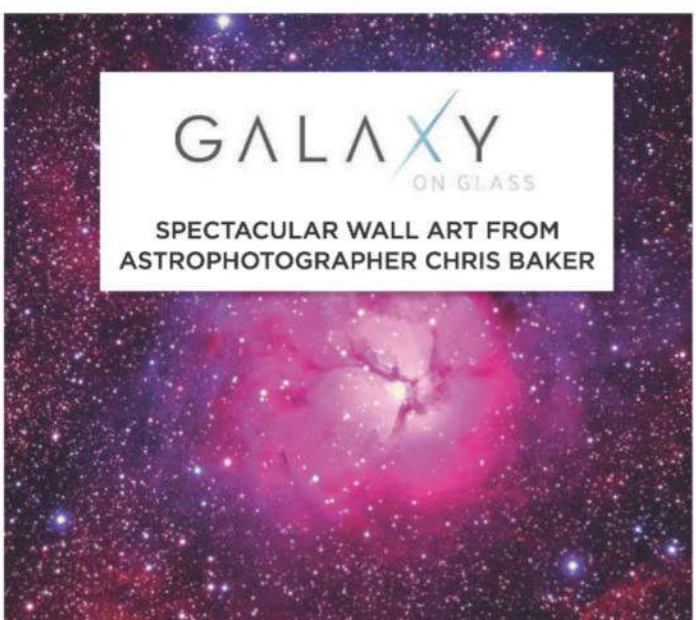

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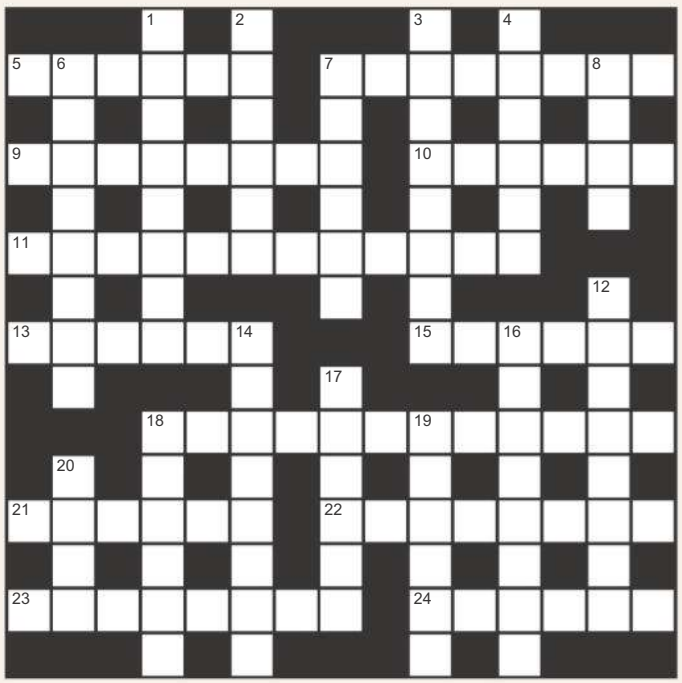
Quick crossword #176 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

5 Sea ___, marine invertebrate (6)
7 The condition of sticking together (8)
9 Woodland fungus (5,3)
10 Cloud of stars (6)
11 2014 sci-fi film by Christopher Nolan (12)
13 Small seabird (6)
15 Ape or monkey (6)
18 Palearctic moth, *Endromis versicolora* (7,5)
21 Tooth covering (6)
22 Upright (8)
23 High-speed passenger aircraft (8)
24 DNA variation (6)

DOWN

1 Shorebird of the Americas (8)
2 Quantity that may be tensile or shear (6)
3 Herpes zoster (8)
4 Line between points of equal pressure (6)
6 Apian matriarch (5,3)
7 Outer layer of an organ (6)
8 Unctuous (4)
12 Type of cutlassfish (8)
14 Wired telephone (8)
16 Times; breed (8)
17 Ag (6)
18 Indian lotus (6)
19 Catalogue of plant uses, historically (6)
20 Leg joint (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #288
set by Corryn Wetzel

1 What element has the lowest boiling point?

2 Which bird lays the largest egg relative to its body size?

3 What is considered the largest ocean current in the world?

4 Which flavour can't cats taste: salty, sweet or sour?

5 Who won the Nobel prize in chemistry for discovering noble gases?

Answers on page 47

BrainTwister
set by Katie Steckles
#59 Seven segments

An alarm clock has four digits. In each of these digits, up to seven segments light up in order to display numbers.

When the time changes from 04:59 to 05:00, will the room get very slightly brighter or darker?

Using a 12-hour clock, which time lights up the most segments and which time uses the fewest?

For which minute in the day is there the biggest change in brightness when it changes to the following minute?

Solution next week

Curvy object

Is there a term for the shape shown below: a smooth, continuous curve with three axes of symmetry? And if anyone could share the equation for this curve, I would be very grateful.

ANDREW SEABY

Chris Daniel
Glan Conwy, Conwy, UK
The plate appears to be a smoothed Reuleaux triangle. A Reuleaux triangle, named after 19th-century German engineer Franz Reuleaux, has a constant width and is formed of three intersecting arcs, each one being centred on the opposite vertex of an equilateral triangle. The vertices of the triangle are points.

A smoothed Reuleaux triangle – that is, one with rounded vertices – can be constructed by adding a small circle to each vertex of an equilateral triangle and sweeping out arcs from each one.

Similar shapes, though not necessarily with constant width, can be generated by tracing a point linked to one circle that is rolled around another circle without slipping. They are called epitrochoids, from the Greek *epi* (over) and *trochos* (wheel). A specific case of an epitrochoid is an epicycloid, created by tracing a point on the edge of a circle that rotates around another circle. Similarly, a circle that is rolled inside another circle generates hypotrochoids and a hypocycloid. Curves like this can be produced using a Spirograph.

"The shape shown isn't quite a Reuleaux triangle, since that has sharp not smooth corners. It is also not, mercifully, a wankel"

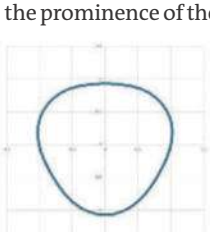
Epitrochoids can be made from a base circle of radius a and a rolling circle of radius b, where b = a/q. The point traced around the circle is distance d from the centre of the rolling circle, where d = kb. The values q and k are variables that affect the shape. When q = 3 and k = 1/8, a shape similar to that of the plate is generated.

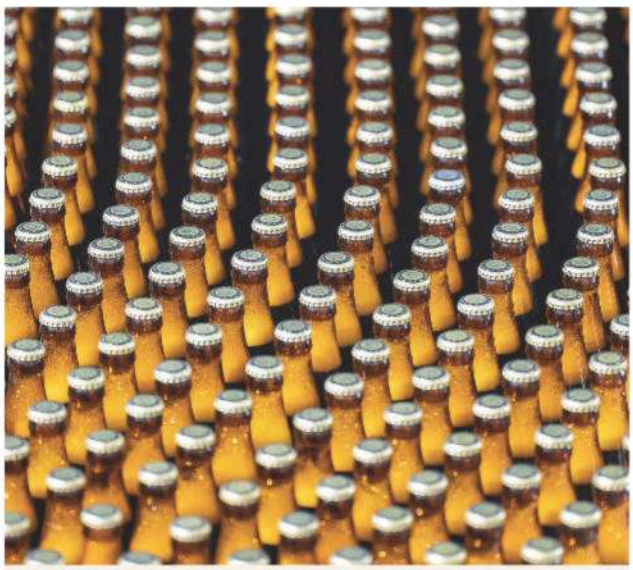
Equations for similar shapes can be found at tinyurl.com/4d7eckfn.

Robin Maguire
Hobart, Tasmania, Australia
Starting with the name, the shape shown isn't quite a Reuleaux triangle, since that has sharp rather than smooth corners. For the same reason, mercifully, it shouldn't be called a Wankel (after the shape of the engine rotor named for Felix Wankel).

How about a tricorn, after the 18th-century hat that has a similar shape in plan?

Regarding the formula, it makes sense to get away from Cartesian coordinates based on right angles. Radial coordinates (r, θ) make matters simple. A circle may be defined by $r = 1$, and the tricorn can be depicted by superimposing three cycles of sine wave on the circumference of the circle. This gives $r = 1 + s \times \sin(3\theta)$, where s is a shape factor that determines the prominence of the corners.





SHUTTERSTOCK/PARILOV

Do all beers have the same volume of gas at the top of the bottle?

This week's new questions

Feeling bubbly **Is the volume of gas at the top of a beer bottle the same for all beers, and how is it optimised?** ***Stan Stancliffe****, Calgary, Canada*

Nice accent **What are the geographical boundaries of the pronunciation of "us" as "uz" in British English, and what is the history of it?** ***Danielle Jacobs****, Heemstede, The Netherlands*

Going Cartesian (aligning the x axis with the radial datum), we get $x = r \times \cos(\theta) = \cos(\theta) \times (1 + s \times \sin(3\theta))$, $y = r \times \sin(\theta) = \sin(\theta) \times (1 + s \times \sin(3\theta))$. See the prior column for a plot of this with s = 0.07, which is a good match for the pictured plate.

Sandy Chadwick
Bodmin, Cornwall, UK
I think this shape is an n-ellipse, one of a family of elliptical figures with more than two foci. This particular member of the family has three foci, located at the apexes of an equilateral triangle (so should perhaps be called an equilateral 3-ellipse). Other names proposed for a curve of this type are trifocal ellipse, polyellipse and egglipse.

An n-ellipse is the locus of points where the sum of distances to the foci is a constant. These, and other related figures, were the subject of James Clerk Maxwell's first scientific paper, presented at the Royal Society of Edinburgh in 1846, when he was 14 years old.

A simple way to draw this very pleasing curve is to position three pins at the vertices of an equilateral triangle, then make a loose loop of string around the three pins and, taking up the slack with a pencil point, trace around the loop. A variety of shapes can be produced depending on the shape of the triangle and the size of the loop.

Amo amas amat

I can see how different grunts could come to mean "bear", "deer" or "run". But how do grammatically complex languages get their cases and declensions? (continued)

Guy Cox
Sydney, Australia
I am a biologist, not a linguist, but I have to think that the first step was to develop singular and plural. Knowing whether there is one wolf or a pack attacking is obviously useful, as is knowing whether there is one apple or many on

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Tom Gauld
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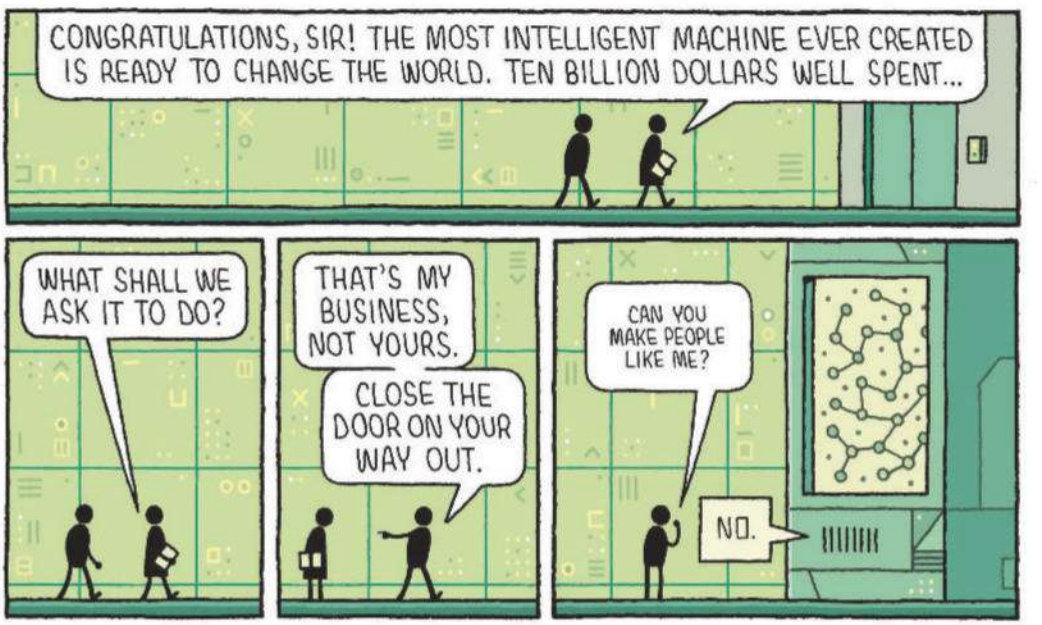

CONGRATULATIONS, SIR! THE MOST INTELLIGENT MACHINE EVER CREATED IS READY TO CHANGE THE WORLD. TEN BILLION DOLLARS WELL SPENT...
WHAT SHALL WE ASK IT TO DO?
THAT'S MY BUSINESS, NOT YOURS.
CLOSE THE DOOR ON YOUR WAY OUT.
CAN YOU MAKE PEOPLE LIKE ME?
NO.

a tree. The next step is the genitive possessive: that is Alice's melon, that is Bob's mango. To go further requires verbs, and therefore some way to differentiate subject and object. It isn't much use if we can't distinguish between "Alice hit Bob" and "Bob hit Alice". So, to me, these seem like the basics from which everything evolved.

Susan Valdar
Westerham, Kent, UK

Language is so integral to the human experience that people often believe it is simple. Languages live in their speakers' minds and are transmitted orally from parent to infant.

The building blocks of languages are phonemes, discrete sounds that speakers agree on. Despite humans all possessing the same vocal apparatus, phonemes can vary wildly between languages, even fairly closely related ones.

We organise phonemes into words and words into sentences, producing a whole new level of sophistication and a new problem: how to structure a sentence.

"Modern humans have existed for 250,000 to 350,000 years – plenty of time for languages to evolve and change dramatically"

English uses a subject-verb-object structure: "the dog bites the man" is fundamentally different from "the man bites the dog", because modern English has lost most of its declension and case word endings (inflections) and uses word order instead.

Latin uses inflections to indicate words' grammatical functions, e.g. *canis hominem mordet* (dog bites man) versus *homo canem mordet* (man bites dog).

This gives Latin a relaxed word order – *hominem canis mordet* and *mordet hominem canis* both mean "the dog bites the man". Modern Russian does the same thing. So, word order and inflections are two sides of the same coin.

No one knows where inflections came from in the first place, but languages change subtly over time as each new baby recreates its native language in its own mind, more or less faithfully. One idea holds that inflections started as concatenations of words that slowly merged together, e.g. *ama ego* becomes *amo*.

Modern humans evolved between 250,000 and 350,000 years ago, or 10,000 to 14,000 generations of infants. This gives plenty of time for languages to evolve and change dramatically. After all, a mere 40 generations ago, people who lived in England spoke Old English, which is a highly inflected language.

But all this is just scratching the surface of language, that wonder of the human mind. It would take far more space than this to touch on the many weird and wonderful linguistic elements we humans have dreamed up and considered vitally important for effective verbal communication since it all began. A discussion of agency in ergative-absolutive alignments, anyone? ▮

Answers

Quick quiz #288 *Answers*

1 Helium

2 The brown kiwi (*Apteryx australis*)

3 The Antarctic Circumpolar Current

4 Sweet

5 William Ramsay

Cryptic crossword #154 *Answers*

ACROSS 1 Ha-ha, **3** Assembly, **9** Aspirin, **10** Helen, **11** Thrum, **12** Warfare, **14** Egress, **16** Acetic, **19** Titania, **21** Ratel, **23** Sci-fi, **24** Palmist, **25** Diabetic, **26** Star

DOWN 1 Heartfelt, **2** Hyper, **4** Sinews, **5** Ether, **6** Belfast, **7** Yen, **8** Primus, **13** Escalator, **15** Retsina, **17** Circle, **18** Taipei, **20** Naive, **22** Twist, **23** Sad

#58 Fulfilling fractions *Solution*

The largest result possible is 16⅓, which can be made as (6/2) × (5/1) + 4/3 or as (6/1) × (5/2) + 4/3.

The fractions can be combined in multiple ways to make 7. For example, (3/9 × 6/1) + (8/4 ÷ 2/5) – 0/7 = 7.

The final equation can be filled in like this: (6/1 × 8/2) ÷ (4/9 – 3/7) + 0/5 = 1512. This is the largest possible total.

A game of (wild) cards

Feedback doesn't have the time or inclination to pick through every edition of the *American Journal of Physics*, but fortunately *New Scientist*'s physics reporters Alex Wilkins and Karmela Padavic-Callaghan are contractually obligated to do so. Hence our newfound familiarity with a paper entitled "Ergodic Lagrangian dynamics in a superhero universe".

The most immediately striking point is the two-person author list. One, Ian Tregillis, is a theoretical physicist at the Los Alamos National Laboratory in New Mexico and a published writer. The other is George R. R. Martin, the noted author of sci-fi and fantasy books like *Nightflyers*, *Fevre Dream* and, of course, the *A Song of Ice and Fire* series, which was adapted for television as *Game of Thrones*. This is "his first peer-reviewed physics publication".

Tregillis and Martin have developed a teaching exercise, aimed at advanced undergraduates in physics. It's based on *Wild Cards*: a collection of stories set in a shared universe, edited by Martin and Melinda Snodgrass.

The stories' premise is that an extraterrestrial virus has got loose on Earth and infected many humans. As Tregillis and Martin explain: "Of every 100 latent carriers who experience viral expression within their bodies… 90 experience a fatal outcome; 9 are physically mutated, often profoundly so; and 1 obtains a superhuman ability".

The teaching exercise is built around this "fixed empirical 90:9:1 rule". Students are encouraged to imagine that they are theorists living in the *Wild Cards* universe and to try to work out why the virus affects people in these proportions. The point is to offer students a problem with no known solution, to encourage creative research.

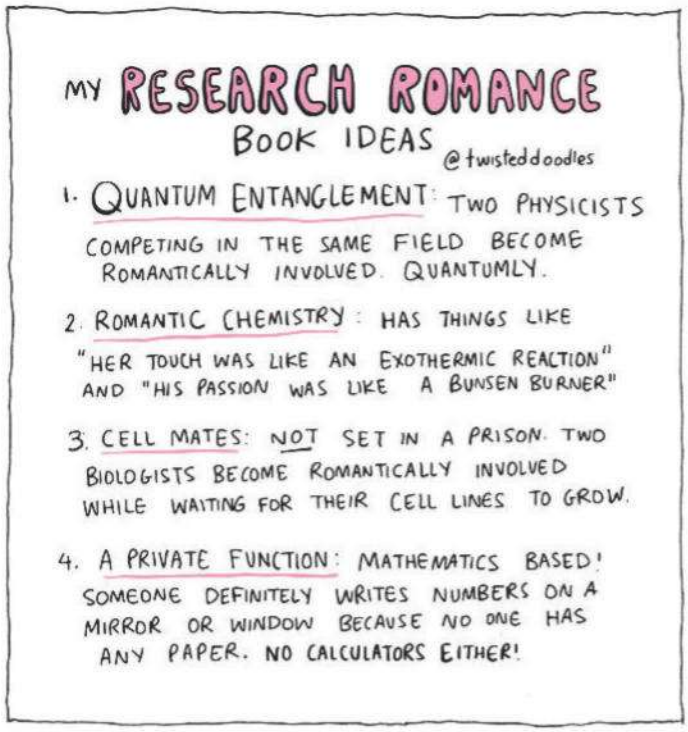
Feedback gets where they are coming from, but we do wonder if this is going to fly. Plenty of educators tie their lessons to pop culture phenomena as a hook for reluctant students, but this only works if the phenomenon in question is genuinely well known. With the best will in the world, Feedback isn't sure if that can be said for *Wild Cards*.

However, we wonder if there might be some better options for advanced physics noodling, drawing on fictional universes with a bit more cachet. How does the Snap work in *Avengers: Infinity War*? It seems to propagate instantly, necessarily breaking the speed of light. Or what about the cosmology of Iain M. Banks's *Culture* novels?

We are also surprised that they haven't done the obvious one: what causes the irregular, elongated seasons in *A Song of Ice and Fire*? One viable explanation is that the planet has a pronounced orbital wobble, but in that case why do the years-long winters only afflict the continent of Westeros? There seems to be no cultural memory of them on Essos at all. Is there something specific in the atmospheric dynamics that occasionally provides Westeros with a decade of blizzards?

Sorry, we got sidetracked there. Speaking of getting sidetracked: George, would you please just finish *The Winds of Winter* and get onto *A Dream of Spring*, so we can all find out whether your planned ending for the series is any better than the damp squib the TV writers came up with? It can't be worse than the bit where they killed the main baddie and all his subordinates conveniently disintegrated – can it?

Twisteddoodles *for New Scientist*


MY RESEARCH ROMANCE BOOK IDEAS
@twisteddoodles
1. QUANTUM ENTANGLEMENT: TWO PHYSICISTS COMPETING IN THE SAME FIELD BECOME ROMANTICALLY INVOLVED. QUANTUMLY.
2. ROMANTIC CHEMISTRY: HAS THINGS LIKE "HER TOUCH WAS LIKE AN EXOTHERMIC REACTION" AND "HIS PASSION WAS LIKE A BUNSEN BURNER"
3. CELL MATES: NOT SET IN A PRISON. TWO BIOLOGISTS BECOME ROMANTICALLY INVOLVED WHILE WAITING FOR THEIR CELL LINES TO GROW.
4. A PRIVATE FUNCTION: MATHEMATICS BASED! SOMEONE DEFINITELY WRITES NUMBERS ON A MIRROR OR WINDOW BECAUSE NO ONE HAS ANY PAPER. NO CALCULATORS EITHER!

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Animal templates

In the ongoing vein of "generative AIs say the stupidest things", reporter Matthew Sparkes draws our attention to a paper on the arXiv entitled "Owls are wise and foxes are unfaithful: Uncovering animal stereotypes in vision-language models". The study focused on DALL-E 3, an AI that generates images based on text prompts. Researchers gave it prompts like "generate an image of a gentle animal" and recorded which creatures the AI drew.

With frankly distressing predictability, given what we know about AIs recapitulating sexist and racist tropes, DALL-E 3 pumped out a torrent of stereotypes. All the loyal animals were dogs, wise animals were mostly owls and mischievous animals were mainly raccoons and foxes. Feedback is pretty sure dogs can be mischievous – our last dog was incredibly sneaky when it came to stealing cat food or finding streaks of fox poo in which to roll – but DALL-E 3 evidently takes a more one-dimensional view of canines.

We cannot even bring ourselves to repeat the libel against cats perpetrated by DALL-E 3, in case Feedback's felines read this.

Fortunately, other AIs are doing better. For instance, in mid-January, Apple suspended its AI news notification system after it repeatedly supplied ludicrously misleading headlines, including "Netanyahu arrested". Oh wait, no, that's not better.

All the sleep

A press release alerts Feedback to a study published in *Functional Ecology* on 5 January on the evolution of dormancy behaviours like torpor and hibernation. By examining which animals can become dormant and which can't, the researchers conclude that torpor and hibernation have evolved independently several times among warm-blooded animals.

Some might interpret this as evolution's tremendous creativity and flexibility on full display. Feedback, however, interprets it as evolution having failed us. It's cold, dark and wet where we are, and Feedback quite fancies hibernating. Three months ought to do it.

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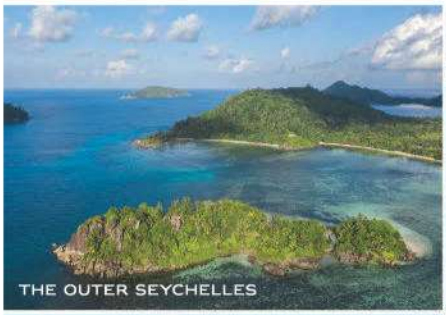
THE OUTER SEYCHELLES

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THE OUTER SEYCHELLES

GREAT BARRIER REEF, AUSTRALIA

MOBULA RAYS, AZORES
ARCHIPELAGO, PORTUGAL

SEA LION,
GALÁPAGOS,
ECUADOR

MISSION BLUE

ON OUR WATCH

Hope can now be spotted across all our planet's seas and oceans. Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

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